The Project Method of Teaching

LOCOMOTIVE BOILERS

PART 1

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INSTRUCTION PAPER

With Examination Questions

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H P Patman

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LOCOMOTIVE BOILERS

(PART 1)

CONSTRUCTION, DETAILS, AND MAINTENANCE

DEVELOPMENT

1. The development of the locomotive boiler during the past 50 years has been a remarkable achievement. In the 70's, the boilers then in use were of the narrow-firebox type, with the size of the firebox limited to the distance between the frames and the driving wheels. Boilers of this type had a heating surface of about 1,000 square feet, heating surface meaning the surface exposed to the heat of the fire or the hot gases. In the 80's the foundation ring was raised and widened so that it would set on the frames, and the width of the firebox was increased so that it would just clear the driving wheels on each side. This increase in grate area led to an increase in the size of the boiler, and the heating surface was increased in proportion, or to 1,800 to 1,900 square feet. The next step was to place the firebox back of the driving wheels and to increase the width so that it would extend out over the wheels, provided they were of comparatively small diameter. If they were not, a pair of wheels of small diameter, called trailing wheels, was placed under the firebox to distribute more equally the weight of the boiler on the wheels.

2. By this arrangement it was possible to have a firebox of a width limited to the clearance of the right of way, and a length limited to the ability of the fireman to shovel the coal.

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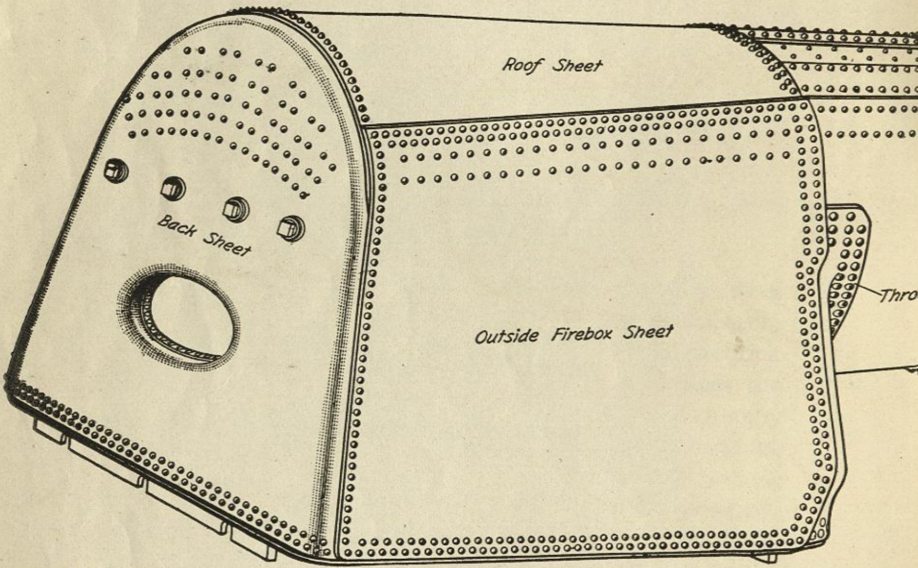
With the adoption of fireboxes of these dimensions, the other parts of the boiler were also increased in size. The cylindrical portion was increased from about 50 inches in diameter to nearly 120 inches as at present with the largest type of locomotives. The tubes were also lengthened from 10 or 12 feet to 18 or 19 feet, and in the boilers of large Mallet engines up to 25 feet.

The increase in the length and diameter of locomotive boilers resulted in an increase in the heating surface, which now ranges from 1,500 to 8,500 square feet. The steam pressure of 100 pounds to 110 pounds per square inch which was used in the 70's was increased to from 130 pounds to 160 pounds to the square inch in the 80's. From that time, the pressure was gradually increased until about 1900, when a pressure of 200 pounds per square inch became common. Pressures of 210 and 250 pounds are in use on some railroads, but the practice is not general, the predominating pressure being from 180 pounds to 200 pounds per square inch.

3. The increase in the size and capacity of locomotive boilers would not be possible were it not for the firebrick arch, the superheater, and the mechanical stoker. The firebrick arch, by reason of its position in the firebox, increases the length of the path of the hot gases through the firebox, thereby insuring better burning of the gases generated during combustion and an increase in the efficiency of the firebox heating surfaces. The superheater heats the steam to a higher temperature after it leaves the boiler, and thereby increases the volume of the steam that is delivered to the cylinders by about 30 per cent. The employment of a superheater permits the use of a boiler of smaller size when the cylinder volume remains the same, or, with a boiler of the same size, an increase of 30 per cent. in cylinder capacity may be obtained as compared with a saturated-steam locomotive. By the use of a superheater, the size of the boiler which otherwise would be very bulky is kept within reasonable limits. Without a superheater, the average locomotive when working very hard would necessitate the boiler being forced beyond its economical capacity. The



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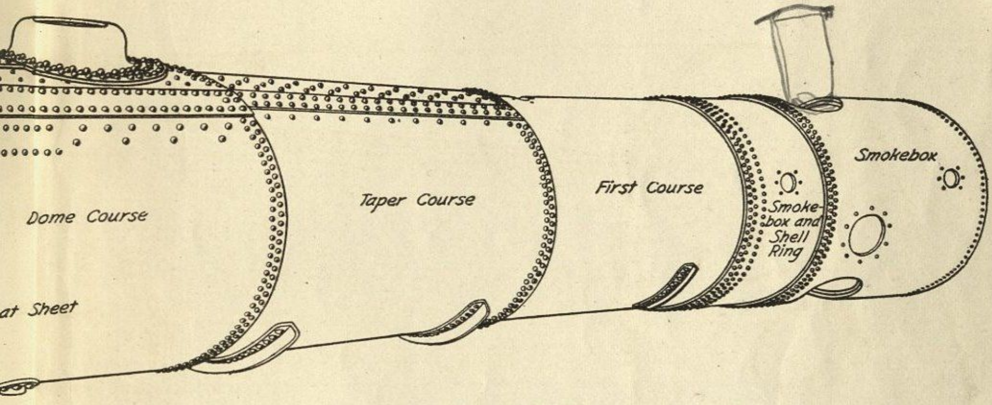
Dome Course
Taper Course
First Course
Smokebox and Shell Ring
Smokebox
at Sheet

Fig. 1

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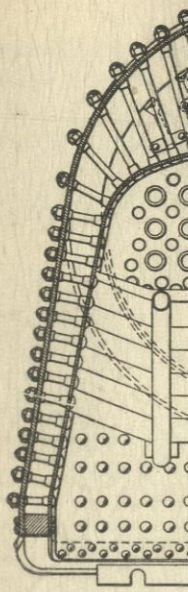

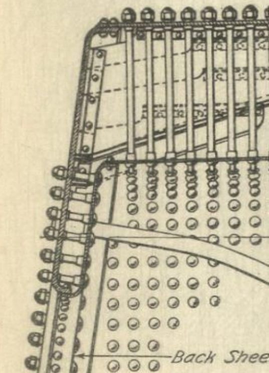

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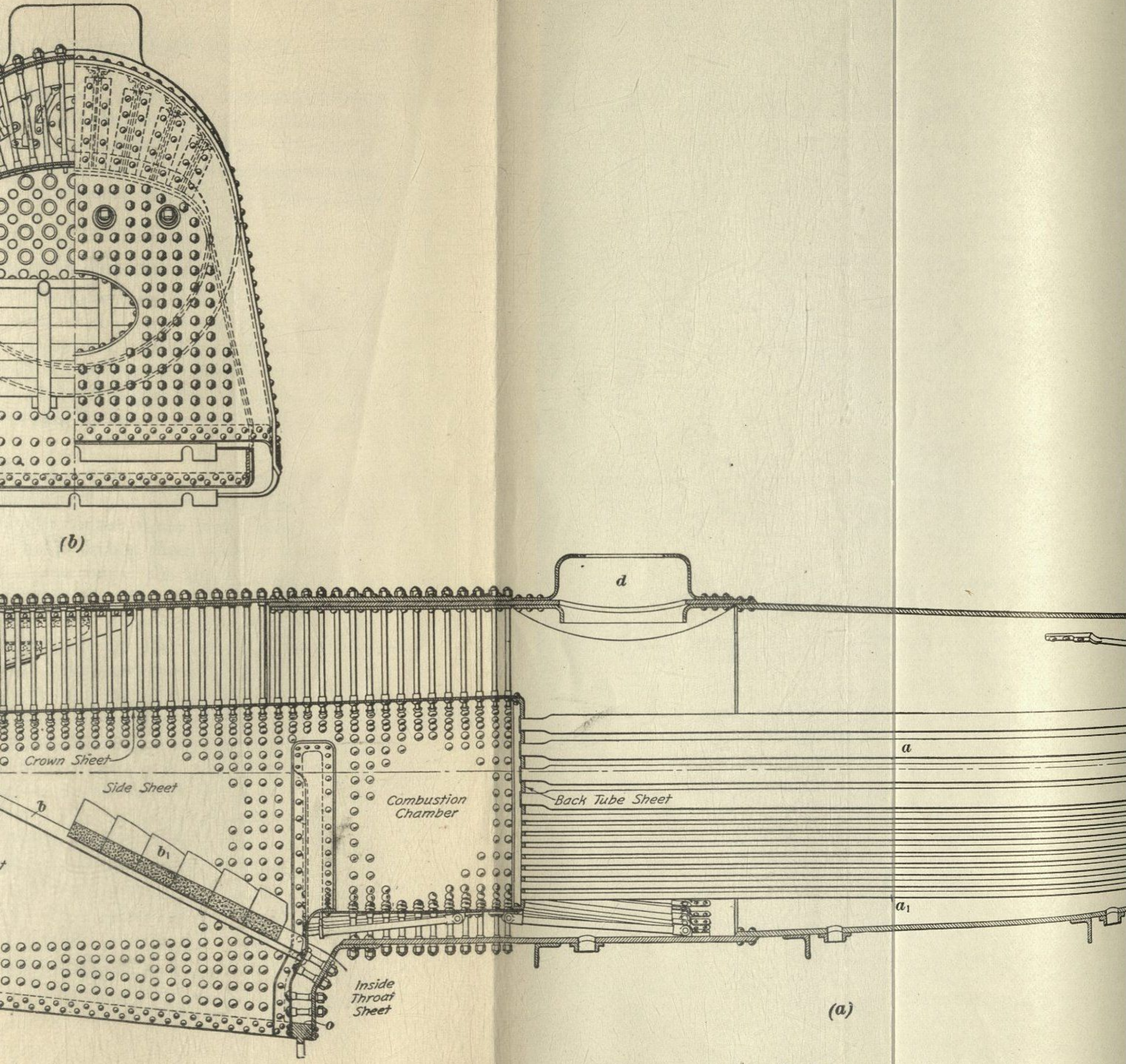
(b)
d
Crown Sheet
Side Sheet
b
b$_1$
Combustion Chamber
Back Tube Sheet
a
a$_1$
Inside Throat Sheet
(a)

Fig. 2

mechanical stoker, which is a device for mechanically firing a boiler, enables a sufficient quantity of coal to be placed in the firebox to develop the full capacity of the boiler. This device is especially adapted to boilers that have a very large grate area such as are used with the Mikado, Santa Fe, and Mallet types of locomotives

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GENERAL DESCRIPTION

4. **Definition.**—The locomotive boiler consists of a steel shell for containing water which is converted into steam by the heat of the fire in the firebox and furnishes the energy to move the locomotive. Locomotive boilers are of the internal multitublar fire-tube type. This means that the firebox is contained within the boiler, and that the boiler contains a large number of tubes and flues.

5. **Names of Exterior Sheets.**—An exterior view of a modern type of locomotive boiler is shown in Fig. 1. The exterior sheets of a boiler consist of the back sheet or head, the roof sheet, the outside firebox sheet (one on each side), the throat sheet, the dome course, the taper course, the first course, the smokebox and shell ring, and the smokebox.

On very long boilers, a course known as the second course is sometimes introduced between the taper course and the first course; with boilers having combustion chambers, a combustion-chamber course is placed next to the roof sheet, instead of the dome course. Sometimes the dome is placed on the combustion-chamber course, this course then being a dome course or a combustion-chamber course. The roof sheet and the two outside firebox sheets may be made in one piece instead of three as shown in Fig. 1. The taper course may have a uniform taper all the way around, in which case it is referred to as the conical course; a taper course is really one in which the taper is on the upper part, the lower part being straight. The dome course and the combustion-chamber course are sometimes made in one piece.

6. **Names of Interior Sheets.**—The interior sheets of a locomotive boiler are shown named in Fig. 2 (*a*) and are as

follows: The front tube-sheet, the back tube-sheet, the crown sheet, the two side sheets, the back sheet or door sheet, and the inside throat sheet. This latter sheet is only necessary in boilers having combustion chambers. With the exception of the front tube-sheet, the sheets just named combined with the grates form the firebox. The grates serve to hold the fuel while it is being consumed.

7. The back and the front tube-sheets are connected by the superheater flues *a* and the small tubes a_1. The flues and tubes serve to convey the smoke and gases from the firebox to the smokebox and also act as stays for the sheets. The inside of the firebox sheets and the tubes and flues are covered with water when the boiler is fired up, as these parts are exposed to

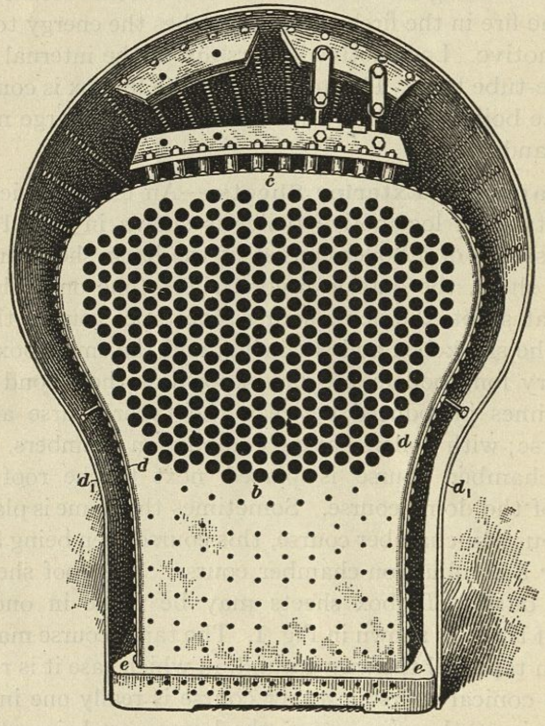


FIG. 3

the heat of the fire on the opposite side. The smokebox or extension front end *c* contains the exhaust nozzle (not shown) and also certain draft appliances, by means of which an even draft is produced through all parts of the fire. The steam dome *d* is a receptable for collecting and holding dry steam and also forms a convenient place for the throttle valve. The combustion chamber is an enlargement of the firebox and is used to promote combustion. The arch tubes *b*, four being generally used, aid the circulation of the water and also serve to support the brick arch b_1.

The outside of the boiler is covered by a lagging to prevent the loss of heat by radiation. The lagging is usually composed of some substance that will not burn, and which is also a poor conductor of heat, such as magnesia and asbestos. The lagging is applied in sections and is covered with a sheet-iron jacket. Boilers were formerly lagged with wood.

8. Interior View of Boiler.—Fig. 3 is a view of a boiler with the throat sheet and the dome course removed, and therefore shows the position of the firebox sheets with respect to the outer sheets of the boiler. This view shows the outer sides, or the water sides, of the firebox sheets with the exception of the back sheet which is at the rear and cannot be seen. The back tube-sheet is marked *b*, the crown sheet, *c*, and the firebox side sheets, *d*. The firebox is, then, a box or compartment within the larger compartment formed by the roof sheet, the outside firebox sheets, and the back sheet. The lower parts of the side sheets *d* and the outside firebox sheets d_1 are riveted to the wrought-iron or steel frame *e*, called the foundation ring or the mud ring. The space that is formed by the firebox side sheet *d*, the mud ring *e*, and the outside firebox sheet d_1 is called the water leg.

9. Throat Sheet.—As shown in Fig. 1, the shape of the upper part of the dome course conforms more or less to the shape of the roof sheet and these two parts can therefore be easily connected together. However, to connect the lower cylindrical part of the boiler to the side sheets requires a sheet of special shape, which is called the throat sheet, one side of which is shown in Fig. 4. The bottom part *e* of the throat sheet is flanged so as to conform to the cylindrical shape of the part of the boiler which rests on and is riveted to it.

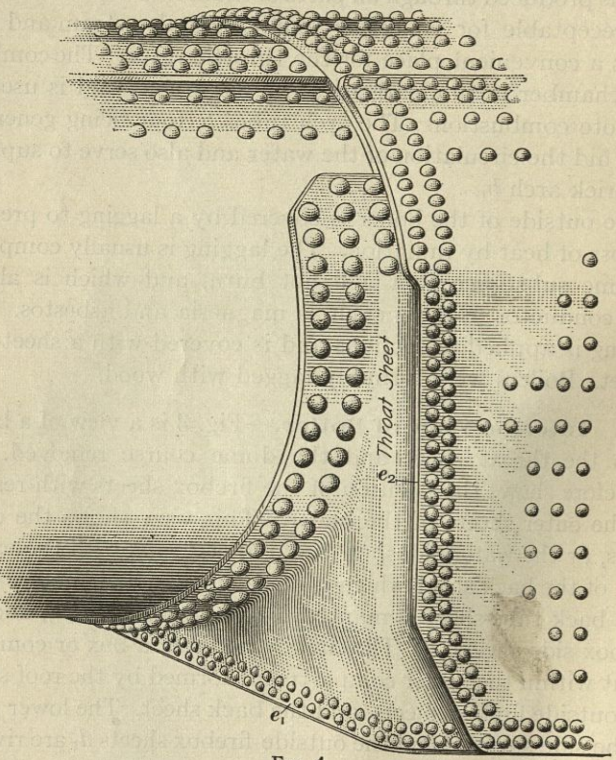


FIG. 4

The sheet is flat where it is riveted to the outside firebox sheets. In some designs, the throat sheet extends entirely around the boiler and therefore connects the entire cylindrical shell with the roof sheet and firebox side sheets.

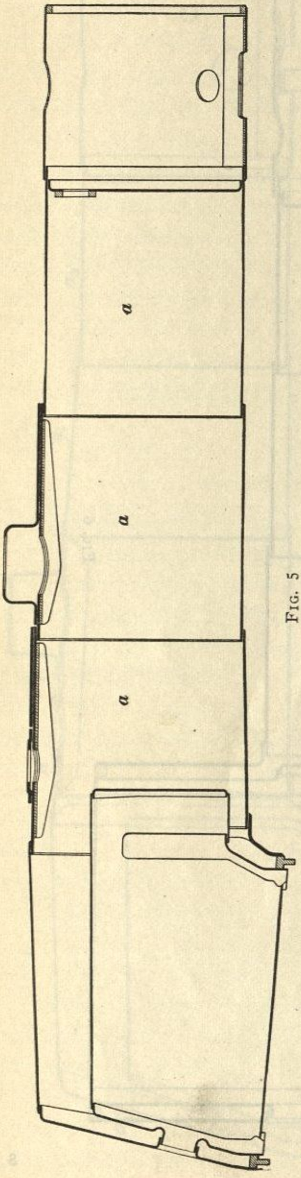


Fig. 5

CLASSIFICATION OF BOILERS

10. Names of Classes.—Locomotive boilers are classified according to their shape and also according to the shape of the firebox. Classified according to shape, boilers are known as straight-top, wagon-top, extended wagon-top, and conical. If the shape of the firebox is considered, locomotive boilers are referred to as narrow-firebox, wide-firebox, Belpaire-firebox, oil-burning-firebox, Jacobs-Shubert-firebox, etc.

A narrow-firebox boiler is one in which the firebox is placed between the frames, and its width thereby restricted to the space between them. With a wide-firebox boiler, the firebox is wider than the frames, and is placed on top of them. All modern locomotive boilers have wide fireboxes, because sufficient grate area must be provided to burn the required amount of coal, and thereby develop full boiler capacity without the rate of combustion being excessive. The illustrations that follow show boilers with wide fireboxes.

11. Straight-Top Boiler. A section taken through a straight-top boiler is shown in Fig. 5. A straight-top boiler is one in which

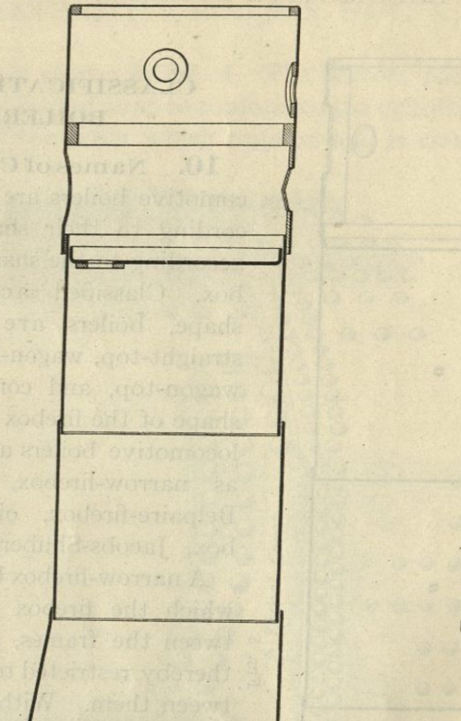


FIG. 6

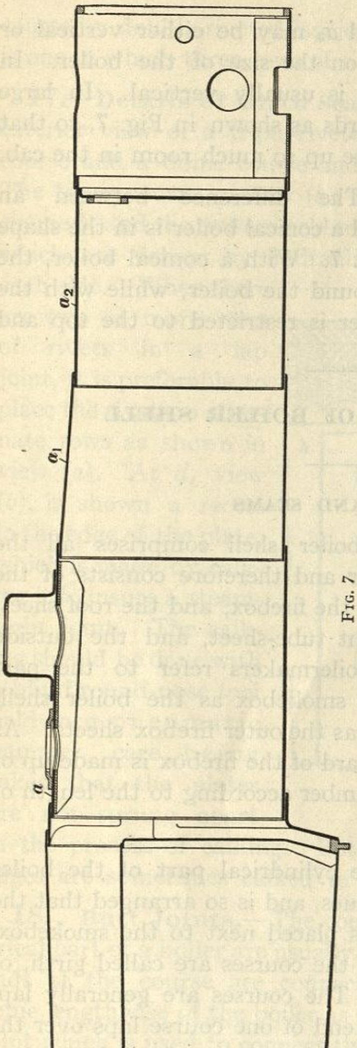


FIG. 7

the cylindrical courses a are of uniform diameter. In some designs, the roof sheet slopes toward the back head, as shown.

12. Wagon-Top Boiler. A sectional view of a wagon-top boiler is given in Fig. 6. This type of boiler has the sloping course a in front of the roof sheet. The steam dome is usually over the firebox, or it may be placed in the sloping course. This type of boiler is no longer in general use.

13. Extended Wagon-Top Boiler.—An extended wagon-top boiler, Fig. 7, is one which has one or more cylindrical courses a next to the roof sheet, a conical course a_1 which tapers down to a smaller diameter, the taper being confined to the top and sides, and one or more cylindrical courses a_2 of reduced diameter next to the smokebox. The cylindrical course a is placed next to the firebox so as to provide a place for the steam dome ahead of the firebox and thus do away with the crown-bar method of staying the crown sheet, which is employed with the wagon-top type. The construction of the back head a_3 may be either vertical or sloping forwards, depending on the size of the boiler. In small boilers, the back sheet is usually vertical. In large boilers, the sheet slopes forwards as shown in Fig. 7, so that the upper portion will not take up so much room in the cab.

14. Conical Boiler.—The difference between an extended wagon-top boiler and a conical boiler is in the shape of the tapering course a_1, Fig. 7. With a conical boiler, the taper extends all the way around the boiler, while with the extended wagon-top, the taper is restricted to the top and sides.

CONSTRUCTION OF BOILER SHELL

JOINTS AND SEAMS

15. Definition.—The boiler shell comprises all the exterior sheets of the boiler and therefore consists of the cylindrical courses in front of the firebox, and the roof sheet, back head, throat sheet, front tube-sheet, and the outside firebox sheets. However, boilermakers refer to the part between the firebox and the smokebox as the boiler shell, and the other exterior sheets as the outer firebox sheets. As shown in Fig. 1, the shell forward of the firebox is made up of courses, and these vary in number according to the length of the boiler.

16. Girth Joints.—The cylindrical part of the boiler shell encloses the tubes and flues, and is so arranged that the course of smallest diameter is placed next to the smokebox. The joints at the junction of the courses are called girth, or transverse, joints or seams. The courses are generally lap-jointed together; that is, the end of one course laps over the end of the course next to it and the two are riveted together. One, two, or three rows of rivets may be used, depending on the size of the boiler. When two rows of rivets are used, the joint is referred to as a double-riveted lap joint. The dome course and the first course, Fig. 1, are connected to the taper course by double-riveted lap joints. A triple-riveted lap joint is one in which three rows of rivets are used.

17. Details of Girth Seam.—In Fig. 8 (*a*) is shown an exterior view of a triple-riveted lap joint, between a taper course and a dome course and view (*b*) is a sectional view. The taper course *a*, view (*b*), fits on the inside of the dome course *b*, and the two are held together by three rows of rivets *c*, which are driven by hydraulic pressure to a full head on each side. When there are two or more rows of rivets in a lap joint, it is preferable to place the rivets in alternate rows as shown in view (*a*). At *d*, view (*b*), is shown a recess in the edge of the plate, which is made by calking it to insure a steam-tight joint. The calking should be done with a blunt round-nose tool held in a pneumatic hammer, care being taken that the plates are not sprung apart in the process of calking. Both the inside and the outside edges are sometimes calked to insure a more uniform job.

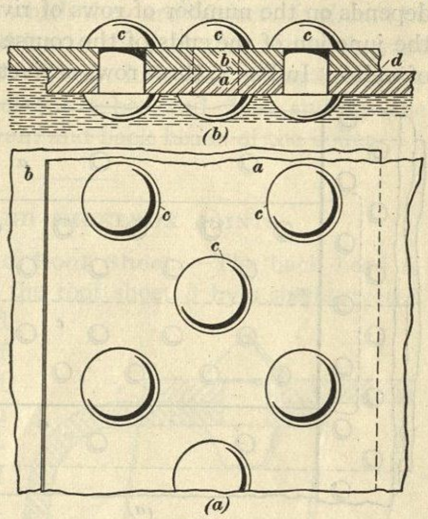


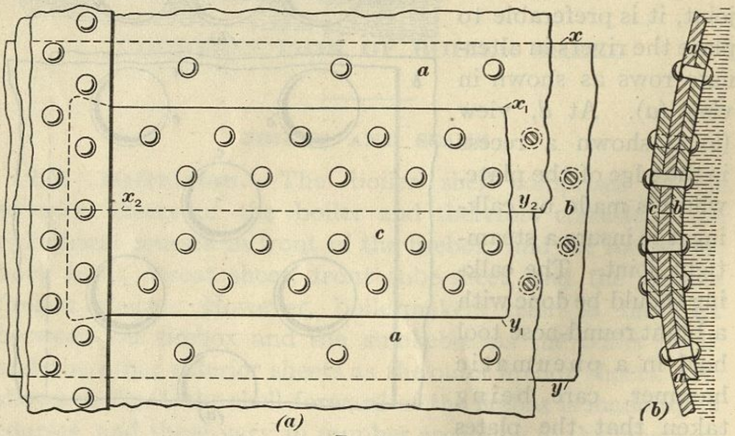
FIG. 8

18. Butt Joints.—The courses that comprise the cylindrical part of a boiler are usually made in one piece. When the ends of the course are connected together, the seam will come lengthwise of the boiler as shown in Fig. 1. The kind of joint which is used to connect the ends of a course together is called a butt joint, because the ends butt together and do not overlap as with the girth joints.

19. Details of Butt Joint.—An exterior view of a butt joint is shown in Fig. 9 (*a*), and view (*b*) is a sectional view.

As shown in view (*b*), the ends *a* of the course are brought together but not overlapped, and stripes, or welts, *b* and *c* which cover the joint are then riveted to the plate on the inside and on the outside.

In view (*a*) the width of the inside welt is the distance between x and y, and the width of the outside welt is the distance between x_1 and y_1. The dotted line x_2 y_2 shows where the ends of the course meet. The name applied to a butt joint depends on the number of rows of rivets used on each side of the junction of the ends of the course and also on the number of welts. In Fig. 9, three rows of rivets are placed on each side of the line x_2 y_2, and as two welts are used the joint is referred to as a triple-riveted, double-welt, butt joint. A quadruple-riveted double-welt butt joint is one in which four rows of rivets and two welts are used, and a quintuple-riveted double-welt butt joint is one which employs five rows of rivets on each side of the seam and has two welts.



(a) (b)

FIG. 9

In the construction of a butt joint the object should be to obtain a form of joint that has as near as possible a strength equal to that of the solid plate. The form of joint shown in Fig. 9 has a strength equal to about 90 per cent. of the solid plate and it is therefore said to have an efficiency of 90 per cent.

20. Relative Stresses on Girth and Lengthwise Joints.—Calculations show that a seam running lengthwise of a boiler is subject to nearly twice the stress that acts upon a girth joint in the same boiler; therefore a joint running lengthwise of the boiler will withstand only one-half the boiler pressure that will be withstood by a girth joint of the same construction. For this reason, care should be taken that lengthwise seams shall be properly constructed to withstand the pressures and stresses to which they are subject. It should be remembered that in addition to the fact that the girth joint is subject to only half the stress, it is also strengthened by the staying properties of the tubes and flues and by the stays that connect the front and back heads of the boiler.

FIREBOX AND SMOKEBOX JOINTS

21. Back Head and Roof Sheet.—The back head *a*, Fig. 10, is connected to the roof sheet *b* by a single-riveted lap joint, which is calked at *c*. A single row of rivets has been found sufficient to carry the strain on the head, on account of the way the head is stayed at other points. The portion of the back head below the crown sheet is rigidly stayed to the back sheet and the foundation ring. Above the crown sheet, the back head is stayed to the roof sheet by diagonal braces similar to those shown at *c* in Fig. 11. Therefore the greater part of the load on the back head is carried by the staybolts and braces. Fig. 11 illustrates how the part of the front tube-sheet above the tubes and flues is braced. The back ends of braces *c* are connected by pins *d* to the **T** irons *e* riveted to the tube-sheet. The front end of the brace is flattened out sufficiently to allow two or three rivets to be used to connect it to the first course.

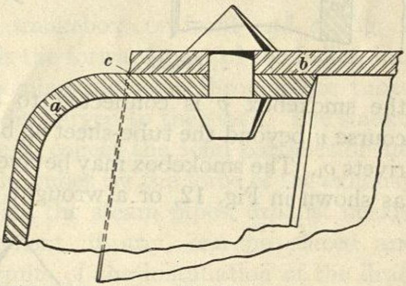


FIG. 10

22. Front Tube-Sheet.—In Fig. 12 is shown how the front tube-sheet *m* is connected to the first course *n* by a single row of rivets which pass through the flange of the sheet and the outer course. The rivets *o* are sometimes driven slightly flattened as shown and sometimes with a flat head on both sides. The first method is the better as it makes it easier to use the tube expanders on the side rows of tubes, and also to calk the rivets should they leak.

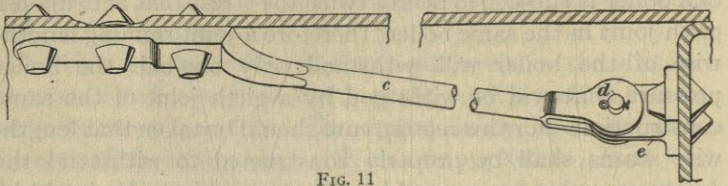


FIG. 11

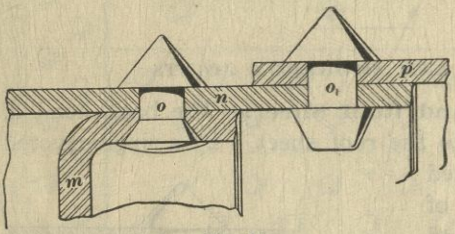


FIG. 12

23. Smokebox and First Course.—Fig. 12 shows that the smokebox *p* is connected to an extension of the first course *n* beyond the tube-sheet *m*, by a single or double row of rivets o_1. The smokebox may be riveted directly to the course *n* as shown in Fig. 12, or a wrought iron ring n_1, Fig. 13, called the smokebox ring, may be inserted between the course *n* and the smokebox. The ring provides a stopping point for the

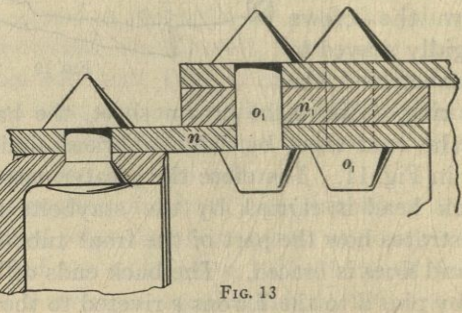


FIG. 13

insulation that is applied to the outside of the boiler. Two rows of rivets o_1 are generally used with the ring n_1.

24. Dome Course and Roof Sheet.—The dome course, or the combustion chamber course, as the case may be, is connected to the roof sheet in the same way as the cylindrical courses are connected together. That is, if the cylindrical courses are connected together by double-riveted lap joints, the same construction is used at the junction of the dome course with the roof sheet. The joint extends down as shown in Fig. 4, until it meets a similar type of joint in the throat sheet and side sheets.

25. Throat Sheet and Side Sheets.—As shown in Fig. 4, the throat sheet is connected to the side sheets and the cylindrical course by a double-riveted lap joint, but in some cases the connection is made by a triple-riveted lap joint.

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THE SMOKEBOX

26. Purpose.—The smokebox, or front end *c*, Fig. 2, as it is commonly called is the forward part of the boiler, into which the products of combustion pass through the tubes, and from which they are discharged to the stack. The smokebox serves as a receptacle to collect the solid particles of fuel that are drawn through the tubes by the force of the exhaust. It provides a space in which the steam pipes, exhaust nozzle, and superheater arrangement, if any, can be placed and inspected, and it also permits of the installation of the draft appliances.

The size of the smokebox is not a matter of very great importance, except that a large one modifies the effect of the exhaust on the fire, while a small one has a very marked effect on the fire. In America, the generally accepted length of smokebox is between 5 and 7 feet. This length is considered as being the most desirable, as it gives a uniformly distributed draft over the entire fire and at the same time provides ample room for the draft appliances.

GENERAL ARRANGEMENT OF SMOKEBOXES

27. Factors Affecting Arrangement.—The arrangement of the smokebox, which means the arrangement of the appliances within it, ranks among the most important details of locomotive-boiler design. On account of the importance of the arrangement, together with the wide range of variables that must be taken into consideration, there is as yet no standard construction that is acknowledged to be the one that will produce the highest efficiency of the boiler under all conditions. Among the variables that affect the smokebox arrangement are the following: The different arrangement of arches, the grate area, the percentage of the openings in the grates, the arrangement of the ash-pan air inlets, and dampers, the kind of fuel, the size of the boiler, the length of the tubes, and whether the locomotive uses saturated or superheated steam. One arrangement representative of the practice on locomotives using saturated steam, and one that is representative of the practice with superheated steam, will be described.

28. Arrangement for Saturated Steam.—The general arrangement of the smokebox appliances with a saturated-steam locomotive is shown in Fig. 14, one side of the smokebox being broken away so that the interior parts can be seen. In this figure, c is the smokebox; c_1, the front tube-sheet; c_2, the first course; c_3, the stack; c_4, the exhaust pipe; c_5, the exhaust nozzle; c_6, the steam pipes; c_7, the diaphragm; c_8, the table plate, shown partly broken away; c_9, the diaphragm apron or damper; c_{10}, the netting; c_{11}, the trap door; c_{12}, the petticoat; c_{13}, the smokebox front ring; c_{14}, the smokebox front; c_{15}, the smokebox door; c_{16}, the smokebox and shell ring.

29. The diaphragm plate c_7 deflects the smoke and products of combustion downwards and tends to equalize the draft through the tubes. It is connected at the bottom to the table plate c_8 by means of an angle iron a. The table plate c_8 is placed on a level with the top of the exhaust pipe c_4. The plates b are placed around the steam pipes c_6, so as to make the joints where the pipes pass through the plates c_8 practically

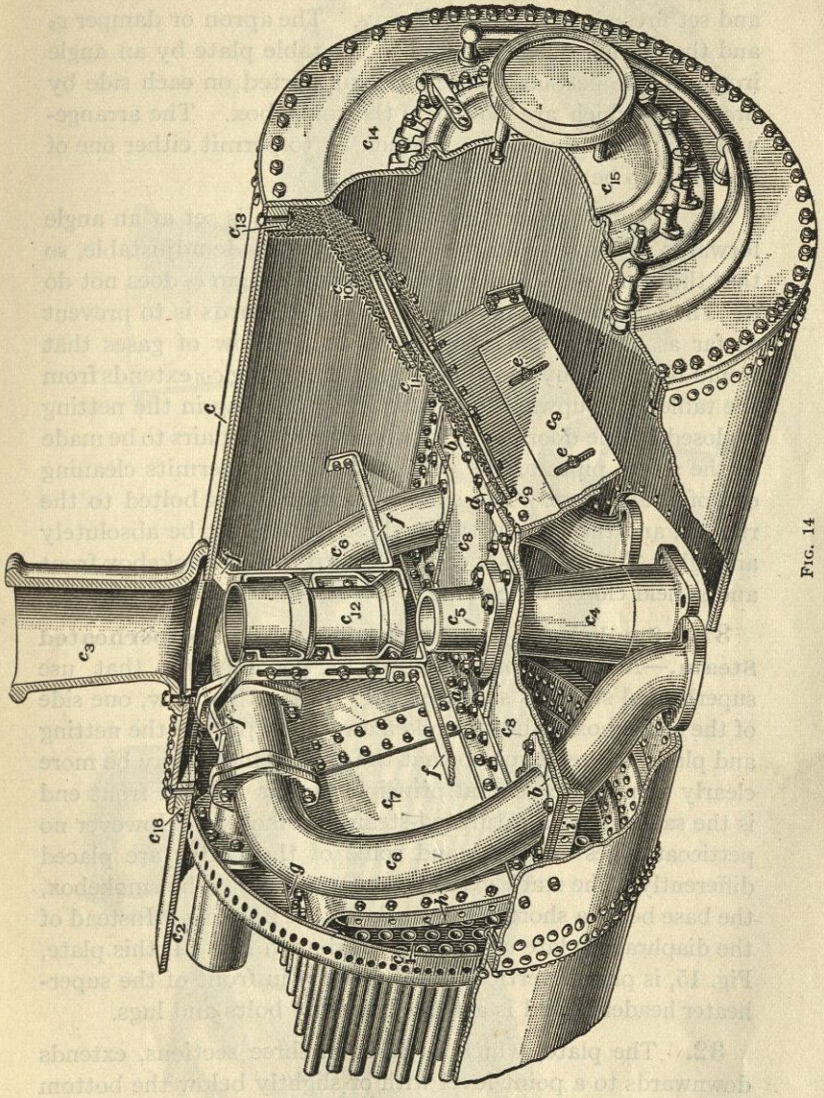

c_{14}
c_{15}
c_{13}
c_{10}
c_{11}
c
b
d
c_9
e
e
c_9
f
c_6
c_8
c_{12}
c_5
c_4
c_3
a
c_8
f
f
c_7
b
c_6
g
c_{16}
c_2
c_1
i

FIG. 14

air-tight. The exhaust then cannot pull live cinders through and set fires along the right of way. The apron or damper c_9 and the netting c_{10} are secured to the table plate by an angle iron *d*. The petticoat pipe c_{12} is supported on each side by brackets *f* which are bolted to the smokebox. The arrangement of the petticoat pipe is such as to permit either one of the pipes to be raised or lowered.

30. The diaphragm apron or damper c_9 is set at an angle forwards as shown, and the lower part is made adjustable, so that the draft can be equalized if the diaphragm c_7 does not do it. The object of inclining the damper forwards is to prevent as far as possible the obstruction to the flow of gases that would be caused by sharp angles. The netting c_{10} extends from the table plate upwards as shown. An opening in the netting is closed by the door c_{11}. This door permits repairs to be made to the steam pipes or the petticoat and also permits cleaning out of the cinders. The smokebox front c_{14} is bolted to the ring c_{13}, and the joint between these parts must be absolutely air-tight. The smokebox door is hinged to the smokebox front and is held closed by clamps.

31. Smokebox Arrangement for Superheated Steam.—A smokebox designed for locomotives that use superheated steam is shown in Fig. 15. In this view, one side of the smokebox is shown broken away and part of the netting and plates are removed so that the arrangement may be more clearly seen. The general principle of this type of front end is the same as for a saturated-steam locomotive. However no petticoat pipes are used and some of the plates are placed differently. The stack extends downwards into the smokebox, the base being a short distance above the nozzle c_5. Instead of the diaphragm plate c_7 being inclined as in Fig. 14, this plate, Fig. 15, is placed vertically and directly in front of the superheater header *R*, and is attached to it by bolts and lugs.

32. The plate, which is made in three sections, extends downwards to a point level with or slightly below the bottom of the superheater flues *a* and connects to the horizontal table plates c_8. These plates extend from the front tube-sheet c_1

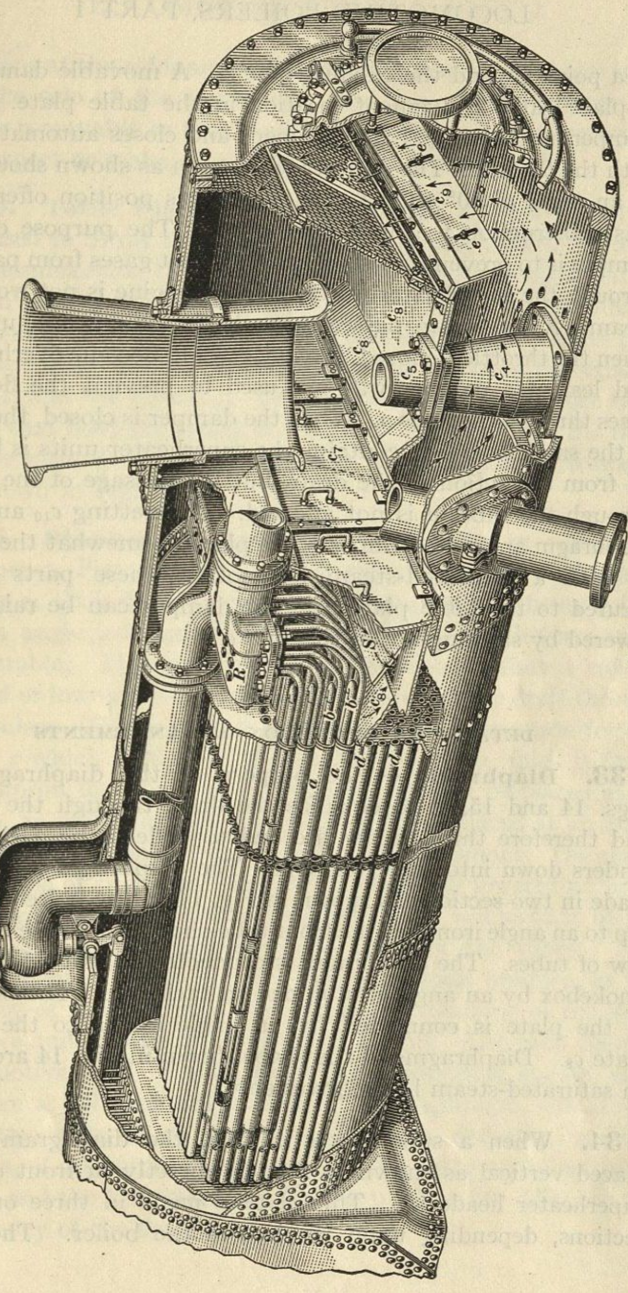


FIG. 15

to a point beyond the exhaust pipe c_4. A movable damper S is placed at a convenient location in the table plate. The damper is so arranged that it opens and closes automatically with the throttle. The damper when open as shown should be at an angle of 60° to the vertical, as this position offers the least obstruction to the flow of gases. The purpose of the damper is to prevent the smoke and the hot gases from passing through the superheater flues when the engine is not working steam. As no steam passes through the superheater units b when the throttle is closed, the units would become overheated and leak if a damper was not used to prevent the flow of gases through the flues a. When the damper is closed, the part of the smokebox that contains the superheater units is boxed off from the action of the draft, but the passage of the gases through the tubes d is not affected. The netting c_{10} and the diaphragm apron or damper c_9 are placed somewhat the same as with a saturated-steam locomotive, these parts being secured to the table plate c_8. The damper can be raised or lowered by slacking off on the nuts e.

DETAILS OF SMOKEBOX ARRANGEMENTS

33. Diaphragm.—The purpose of the diaphragm c_7, Figs. 14 and 15, is to equalize the draft through the tubes and therefore through the fire and to deflect the gases and cinders down into the front end. The diaphragm is usually made in two sections as shown in Fig. 14 and is bolted at the top to an angle iron g on the front tube-sheet just above the top row of tubes. The diaphragm is connected to the side of the smokebox by an angle iron h, one on each side. The bottom of the plate is connected by an angle iron a to the table plate c_8. Diaphragms of the shape shown in Fig. 14 are used on saturated-steam locomotives only.

34. When a superheater is used, the diaphgram c_7 is placed vertical as shown in Fig. 15, directly in front of the superheater header R. This plate is made in three or four sections, depending upon the size of the boiler. The two sections at the sides are bolted to the header and to angle irons on the side of the smokebox. The two center sections are made removable so that they can be taken off when necessary to inspect or make repairs to the superheater units.

35. Table Plates.—The table plates c_8, Figs 14 and 15, are used to throw the sparks downwards and toward the front of the smokebox. They are fastened to the diaphragm plate c_7 by an angle iron *a* and to angle irons *i*, Fig. 14, on the sides of the smokebox. The plates are connected to the exhaust pipe at the center usually by inserting them between the exhaust pipe c_4 and the nozzle c_5. They are held securely by the same bolts that hold the nozzle to the pipe. In some cases the table plates instead of being horizontal, slope slightly downwards as shown in Fig. 15.

36. Diaphragm Apron.—The diaphragm apron, or damper c_9, Figs. 14 and 15, is located at the front of the table plates c_8. It is made in two parts, the upper part being bolted to an angle iron and therefore fixed, but the lower part is adjustable. This part is made adjustable so that it can be raised or lowered when necessary to equalize the draft through the tubes. This is provided for by slotting the apron for the bolts *e* which hold it to the part of the plate which is fixed. The apron may be placed vertical or it may be placed at an angle, as shown in Figs. 14 and 15. When placed at an angle it offers less resistance to the passage of the smoke. The apron should be of such dimensions that when it is lowered as far as it will go the area of the opening beneath it will be 63 to 68 per cent. of the total cross-sectional area of the tubes. The adjustment of the apron is a matter of local practice, as the quality of the fuel used may affect the steaming of the locomotive and require an adjustment to suit. Also each class of locomotive, and in some cases each individual engine, may require a different adjustment. The diaphragm, the apron, and the table plates really constitute the deflector, or draft plates, of a locomotive smokebox. The netting, the petticoat pipe, and the long stack are for the purpose of adding to the efficiency of the draft appliances.

37. Action of Apron.—The action of the apron c_9, Figs. 14 and 15, is as follows: Lowering the apron causes the draft to be stronger through the lower rows of tubes, and checks flow somewhat through the upper rows. This causes the fire to burn better on the forward part of the grates or next to the tube-sheet. Raising the apron, reduces the force of the draft through the lower rows of tubes and strengthens the draft through the upper rows, and the fire will therefore burn better on the rear grates or next to the door. Unless care is taken in the adjustment, the apron may be located so as to obstruct the flow of the gases, in which event it would be a hindrance rather than a help to the free steaming of the locomotive. If the apron is placed too close to the front tube-sheet, the draft will be seriously restricted and the locomotive will be termed "hot at the door," that is the draft will be so weak that soot will accumulate on the fire-door.

38. Netting.—The netting c_{10}, Figs. 14 and 15, extends upwards from the point where the table plate c_8, and the apron c_9 meet, to the top and front of the smokebox. Its purpose is to prevent any large sparks from being pulled through from the firebox and thrown out of the stack by the action of the exhaust. The netting consists of a network of wires about $\frac{1}{8}$ inch in diameter, with a mesh of about $\frac{3}{16}$ to $\frac{1}{4}$ inch square, or the netting may consist of a perforated steel plate. The netting is held in position by bolting it to the table plate c_8 and to angle irons on the sides and top of the smokebox, or it may be bolted to a piece of plate which extends down a short distance from the top of the smokebox. The total area of the openings in the netting should if possible be equal to or greater than the total tube area of the boiler.

The netting obstructs the flow of gases to such an extent that the size of the nozzle must be decreased slightly to produce the same amount of draft that would be obtained if no netting were used.

39. Petticoat Pipe.—Two views of the petticoat pipe c_{12}, Fig. 14, are given in Fig. 16 (*a*) and (*b*). The petticoat pipe consists of two pieces of pipe, each belled out slightly at the bottom as shown. The upper part is called the sleeve and the lower part the petticoat. These parts, view (*a*), are bolted to the bracket c_{18} which is used to secure them to the smokebox. As shown in view (*b*) the holes for the bolts c_{19} in the bracket are slotted, and therefore either of the pipes can be raised or lowered. The petticoat pipe was originally designed for locomotives with short front ends or smokeboxes, and served the purpose of equalizing the draft through the tubes. It was therefore made adjustable as shown. With modern locomotives, the only function of the petticoat pipe is to increase the length of the stack, and thereby confine the smoke and gases within the pipe so that the exhaust has a better chance of giving them an upward motion. As the petticoat pipe is really an extension of the stack, it is usually more convenient to do away with the pipe and extend the stack down into the smokebox instead.

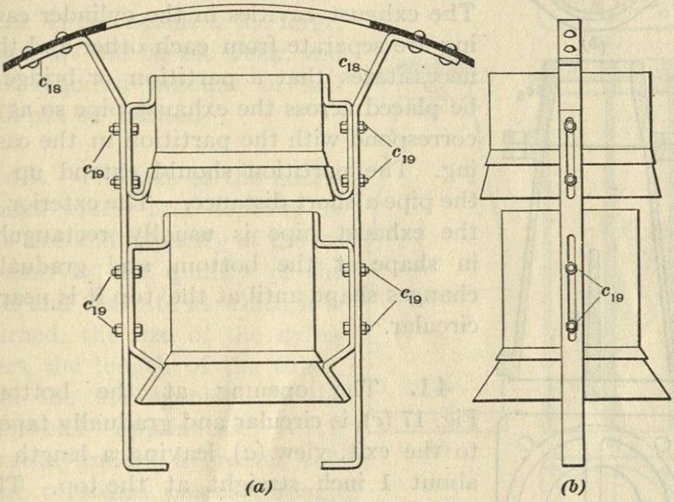
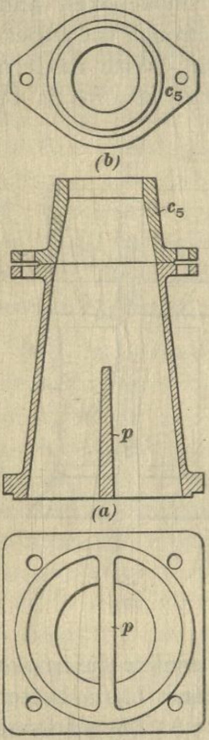


FIG. 16

When a petticoat pipe is used, the recommended practice is to fit it on tight to the base of the stack directly in line with the center of the stack, and make it non-adjustable. If the center of the pipe is out of line with the center of the stack the efficiency of the exhaust jet is lowered.

40. Exhaust Pipe.—The exhaust pipe c_4, Figs. 14 and 15, is made of cast iron and is used to conduct the exhaust steam from the cylinders to a proper point in the smokebox. A sectional view of an exhaust pipe with the exhaust nozzle c_5 bolted to it is shown in Fig. 17 (*a*); (*b*) is a top view of the nozzle c_5 and view (*c*) shows the bottom of the exhaust pipe. The exhaust pipe is bolted to the cylinder casting at a point directly over the exhaust cavities and is so placed as to be directly under the center of the stack. The exhaust cavities in the cylinder casting are separate from each other and this necessitates that a partition or bridge p be placed across the exhaust pipe so as to correspond with the partition in the casting. The partition should extend up in the pipe a short distance. The exterior of the exhaust pipe is usually rectangular in shape at the bottom, and gradually changes shape until at the top it is nearly circular.



(*b*)

(*a*)

(*c*)

FIG. 17

41. The opening at the bottom, Fig. 17 (*c*), is circular and gradually tapers to the exit, view (*a*), leaving a length of about 1 inch straight at the top. The exhaust pipe should be as short as possible with a proper arrangement of the diaphragm and netting, provided this does not make it less than 19 inches high. Should there be any cause for a reduction in the area of the exhaust opening, the reduction should always be made at the nozzle c_5 and not in the pipe. In a double exhaust pipe, as shown in Fig. 18, the partition p extends up to the top of the pipe. On account of the arrangement of the partition, this type requires a double exhaust nozzle; that is, one with two separate openings, as shown in view (*d*).

42. Exhaust Nozzle.—The exhaust nozzle c_5, Figs. 17 (*b*) and 18 (*d*) is the end piece which is bolted to the exhaust pipe. The opening through the nozzle should be of such a size as to cause the steam which passes through it to produce the desired draft on the fire. If the exhaust nozzle is unduly contracted, the force of the exhaust steam will be extremely violent, and holes will be torn in the fire. A contracted nozzle will also increase the back pressure in the cylinders. If the nozzle is too large, the draft will be too weak, and the required amount of fuel will not be burned.

43. The size of the nozzle varies widely and depends on the size and capacity of the locomotive, the quality of the fuel and the rate at which it is burned, the size of the cylinders, the length of the tubes, and the arrangement of the front-end appliances. With large cylinders, a greater volume of steam passes through the nozzle at each exhaust and the nozzle must therefore be larger than when the cylinders are smaller. If the rate of combustion is high, a contracted nozzle is necessary so that it will create a stronger draft and thereby draw a larger volume of air through the firebox. In locomotives of large capacity with tubes ranging in length from 20 feet to 25 feet, a stronger draft is necessary to pull the hot gases through the tubes so that the rate of evaporation per square foot will not be reduced. This condition requires a reduction in the area of the exhaust nozzle.

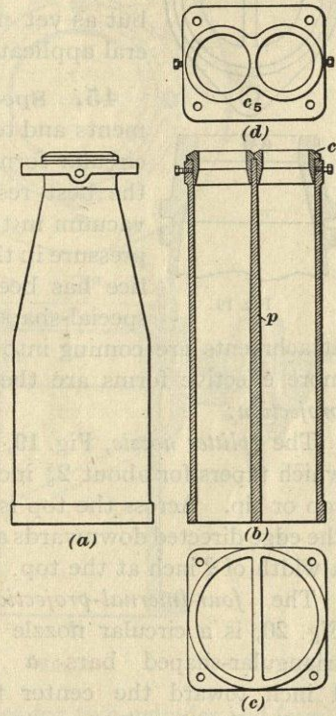


FIG. 18

44. With such a wide range of variables, it is impossible to have one size of nozzle that is adapted to all conditions of service. Numerous attempts have been made to design an exhaust nozzle the opening through which could be varied to suit the different conditions. A number of variable exhaust nozzles have been tried out, but as yet none has proved worthy of general application.

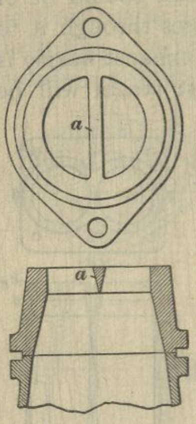


Fig. 19

45. Special Nozzles.—Recent experiments and tests have demonstrated that the circular form of exhaust nozzle does not give the best results in regard to the highest vacuum in the smokebox and the least back pressure in the cylinders. The general practice has been to use circular nozzles, but special-shaped nozzles or those having special attachments are coming into more general use. Among the more effective forms are the *splitter*, and the *four-internal-projection*.

The *splitter nozzle*, Fig. 19, is one that has a circular inlet, which tapers for about $2\frac{5}{8}$ inches, and then is straight to the top or tip. Across the top is fitted a triangular piece *a* with the edge directed downwards and having a width of $\frac{3}{8}$ inch at the top.

The *four-internal-projection nozzle*, Fig. 20, is a circular nozzle which has triangular-shaped bars *a* projecting 1 inch toward the center from four equally distant points on the edge.

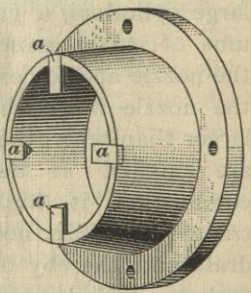


Fig. 20

46. Nozzles for Mallet Locomotives.—With Mallet locomotives, which have two sets of cylinders, the exhaust pipe and nozzle are arranged as shown in Fig. 21, in which (*a*) is a top view and (*b*) a sectional view. The arrangement is really two separate pipes one on the inside of the other, and permits one nozzle to do the work of two. When the engine is working compound, the exhaust steam from all the cylinders passes through the nozzle a; when working simple, the exhaust from the low-pressure cylinders passes through the nozzle a, and from the high pressure cylinders through the nozzle b. The blower pipe is marked a_1; the steam from the blower passes through the projections a_3.

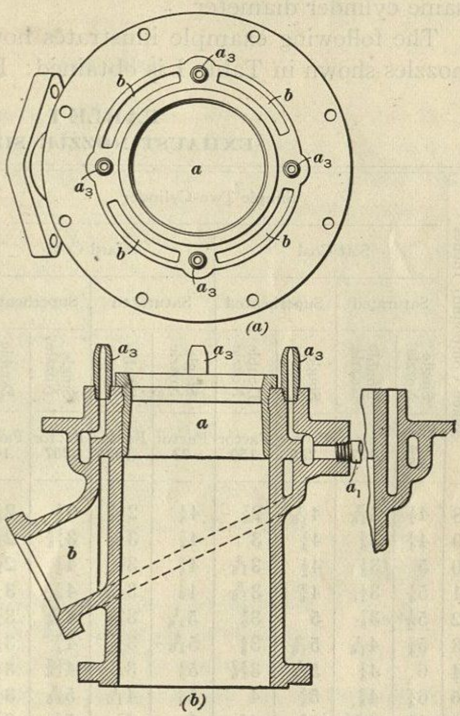


Fig. 21

47. Diameter of Exhaust Nozzle. The American Locomotive Company determines the diameter of the exhaust nozzle by multiplying the diameter of the cylinder by a certain factor, .25, .177, etc., which is found under the heading *Single Nozzle* or *Double Nozzle* in Table I, which shows the standard practice of that company.

This table shows the diameter of the exhaust nozzles for two-cylinder and four-cylinder locomotives burning soft and hard coal and using saturated or superheated steam. The diameter of the cylinders ranges from 18 inches to 32 inches.

The length of the stroke and the steam pressure are not taken into account when considering the size of the exhaust nozzle. The practice of the American Locomotive Company is to use single nozzles, without bridges, for soft coal, oil, and lignite, and double circular nozzles for hard coal. If a bridge is specified, but the size of the nozzle is not given, a nozzle of larger diameter is used to preserve the net area given in the table. The nozzles for oil-burning locomotives are from $\frac{1}{8}$ inch to $\frac{1}{4}$ inch larger than for soft-coal-burning locomotives of the same cylinder diameter. -

The following example illustrates how the diameter of the nozzles shown in Table I is obtained: Let it be assumed that

TABLE I
EXHAUST-NOZZLE SIZES

Diameter of Cylinder (High-Pressure When Compound) Inches	Simple Two-Cylinder								Compound Four-Cylinder (Mallet)			
	Soft Coal				Hard Coal				Soft Coal			
	Saturated		Superheated		Saturated		Superheated		Saturated		Superheated	
	Single Nozzle	Double Nozzle	Single Nozzle	Double Nozzle	Single Nozzle	Double Nozzle	Single Nozzle	Double Nozzle	Single Nozzle	Double Nozzle	Single Nozzle	Double Nozzle
	Factor .25	Factor .177	Factor .225	Factor .159	Factor .23	Factor .163	Factor .207	Factor .147	Factor .325	Factor .230	Factor .293	Factor .207
18	$4\frac{1}{2}$	$3\frac{3}{16}$	$4\frac{1}{16}$	$2\frac{7}{8}$	$4\frac{1}{8}$	$2\frac{15}{16}$	$3\frac{3}{4}$	$2\frac{5}{8}$	$5\frac{7}{8}$	$4\frac{1}{8}$	$5\frac{1}{4}$	$3\frac{3}{4}$
19	$4\frac{3}{4}$	$3\frac{3}{8}$	$4\frac{1}{4}$	3	$4\frac{3}{8}$	$3\frac{1}{8}$	$3\frac{15}{16}$	$2\frac{13}{16}$	$6\frac{3}{16}$	$4\frac{3}{8}$	$5\frac{9}{16}$	$3\frac{15}{16}$
20	5	$3\frac{1}{2}$	$4\frac{1}{2}$	$3\frac{3}{16}$	$4\frac{5}{8}$	$3\frac{1}{4}$	$4\frac{1}{8}$	$2\frac{15}{16}$	$6\frac{1}{2}$	$4\frac{5}{8}$	$5\frac{7}{8}$	$4\frac{1}{8}$
21	$5\frac{1}{4}$	$3\frac{11}{16}$	$4\frac{3}{4}$	$3\frac{5}{16}$	$4\frac{7}{8}$	$3\frac{7}{16}$	$4\frac{3}{8}$	$3\frac{1}{16}$	$6\frac{13}{16}$	$4\frac{13}{16}$	$6\frac{1}{8}$	$4\frac{3}{8}$
22	$5\frac{1}{2}$	$3\frac{7}{8}$	5	$3\frac{1}{2}$	$5\frac{1}{16}$	$3\frac{5}{8}$	$4\frac{9}{16}$	$3\frac{1}{4}$	$7\frac{1}{8}$	$5\frac{1}{16}$	$6\frac{7}{16}$	$4\frac{9}{16}$
23	$5\frac{3}{4}$	$4\frac{1}{16}$	$5\frac{3}{16}$	$3\frac{5}{8}$	$5\frac{5}{16}$	$3\frac{3}{4}$	$4\frac{3}{4}$	$3\frac{3}{8}$	$7\frac{1}{2}$	$5\frac{5}{16}$	$6\frac{3}{4}$	$4\frac{3}{4}$
24	6	$4\frac{1}{4}$	$5\frac{7}{16}$	$3\frac{13}{16}$	$5\frac{1}{2}$	$3\frac{7}{8}$	$4\frac{15}{16}$	$3\frac{1}{2}$	$7\frac{13}{16}$	$5\frac{1}{2}$	$7\frac{1}{16}$	$4\frac{15}{16}$
25	$6\frac{1}{4}$	$4\frac{3}{8}$	$5\frac{5}{8}$	4	$5\frac{3}{4}$	$4\frac{1}{16}$	$5\frac{3}{16}$	$3\frac{11}{16}$	$8\frac{1}{8}$	$5\frac{3}{4}$	$7\frac{5}{16}$	$5\frac{3}{16}$
26	$6\frac{1}{2}$	$4\frac{9}{16}$	$5\frac{7}{8}$	$4\frac{1}{8}$	6	$4\frac{1}{4}$	$5\frac{3}{8}$	$3\frac{13}{16}$	$8\frac{7}{16}$	6	$7\frac{5}{8}$	$5\frac{3}{8}$
27	$6\frac{3}{4}$	$4\frac{3}{4}$	$6\frac{1}{8}$	$4\frac{5}{16}$	$6\frac{1}{4}$	$4\frac{7}{16}$	$5\frac{9}{16}$	4	$8\frac{3}{4}$	$6\frac{3}{16}$	$7\frac{15}{16}$	$5\frac{9}{16}$
28	7	$4\frac{15}{16}$	$6\frac{5}{16}$	$4\frac{7}{16}$	$6\frac{7}{16}$	$4\frac{9}{16}$	$5\frac{13}{16}$	$4\frac{1}{8}$	$9\frac{1}{8}$	$6\frac{7}{16}$	$8\frac{3}{16}$	$5\frac{13}{16}$
29	$7\frac{1}{4}$	$5\frac{1}{8}$	$6\frac{1}{2}$	$4\frac{5}{8}$	$6\frac{11}{16}$	$4\frac{3}{4}$	6	$4\frac{1}{4}$	$9\frac{7}{16}$	$6\frac{11}{16}$	$8\frac{1}{2}$	6
30	$7\frac{1}{2}$	$5\frac{5}{16}$	$6\frac{3}{4}$	$4\frac{3}{4}$	$6\frac{7}{8}$	$4\frac{7}{8}$	$6\frac{3}{16}$	$4\frac{7}{16}$	$9\frac{3}{4}$	$6\frac{7}{8}$	$8\frac{13}{16}$	$6\frac{3}{16}$
31	$7\frac{3}{4}$	$5\frac{1}{2}$	7	$4\frac{15}{16}$	$7\frac{1}{8}$	$5\frac{1}{16}$	$6\frac{7}{16}$	$4\frac{9}{16}$	$10\frac{1}{16}$	$7\frac{1}{8}$	$9\frac{1}{16}$	$6\frac{7}{16}$
32	8	$5\frac{11}{16}$	$7\frac{1}{4}$	$5\frac{1}{16}$	$7\frac{3}{8}$	$5\frac{1}{4}$	$6\frac{5}{8}$	$4\frac{11}{16}$	$10\frac{3}{8}$	$7\frac{3}{8}$	$9\frac{3}{8}$	$6\frac{5}{8}$

it is desired to know the diameter of a single nozzle for a saturated-steam locomotive having a 20-inch cylinder and burning soft coal. This diameter, 20, multiplied by the factor .25 given at the top of the column, gives 5, which is the nozzle diameter shown in the table. If a double nozzle was specified, the diameter of each of the nozzle openings would be $20 \times .177 = 3\frac{1}{2}$ inches. Where the table gives the diameter in sixteenths, the next smaller eighth is to be used.

DRAFT

48. Cause of Draft.—Draft in a locomotive is due to a difference in pressure on the gases in the firebox and in the smokebox. Draft is divided into two classes, *natural* and *forced*. With natural draft no apparatus or force is used to induce the flow of gases, other than the difference in the weight of the hot gases in the firebox and stack and the cooler air outside. The draft through a locomotive boiler when the engine is standing and the blower not working is natural draft. Forced draft, as the name implies, means that the draft is induced by other means. The flow of air through the grates, firebox, and tubes into the smokebox and out the stack when the locomotive is working is an example of forced draft.

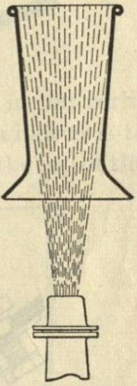


FIG. 22

49. Action of Exhaust in Producing Draft.—The action of the exhaust steam in producing a draft is as follows: The steam after it has completed its work in the cylinders passes through the exhaust pipe and the stack to the atmosphere. The steam in passing through the smokebox carries some of the air with it by induced action, and this tends to cause a partial vacuum in the smokebox. The pressure of the atmosphere outside of the boiler forces fresh air into the ash-pan, through the fire and tubes, and into the smokebox to replace the air which was taken away by the exhaust steam, and thereby creates a draft. The rapidity with which the air and the hot gases change their relative positions depends upon the force of the exhaust steam; the greater the force of the exhaust the stronger will be the draft through the fire. The term partial vacuum as here used means that the pressure of the gases in the smokebox after an exhaust is less than the pressure of the atmosphere, which is about 15 pounds to the square inch. The jet of exhaust steam should not fill the stack whether it is large or small until at a point very near the top as shown in Fig. 22.

THE BLOWER

50. Arrangement and Action.—The action of the exhaust steam in passing through the exhaust nozzle produces a draft through the fire only when the engine is working steam. The blower provides a means whereby a draft is produced when the engine is standing or running with steam shut off. The blower consists of a pipe which conveys steam from a valve on the back boiler head to the exhaust nozzle, or at a point near the base of the stack.

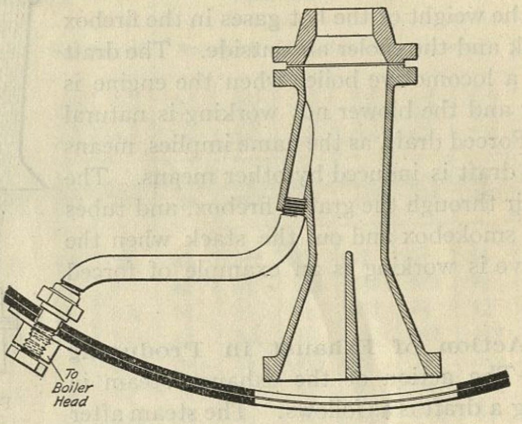


FIG. 23

Figs. 23 and 24 show two different arrangements of the blower pipe at the smokebox. As shown in Fig. 23, the pipe from the boiler head connects outside the smokebox to a pipe that enters the exhaust pipe or the exhaust nozzle. A plug is provided at the junction of the pipes so that a steam hose can be connected and a draft created when the boiler is fired up in the roundhouse. The blower pipe may be connected to the side of the exhaust pipe as shown in Fig. 23, or the pipe may be screwed into the exhaust nozzle as shown in Fig. 24, the outlet for the steam being through the small holes in the vertical projections *c*. The simplest arrangement for a blower is to bend a pipe in the smokebox until the end is near the top of the nozzle and directly in line with the center of the stack. When the blower is in operation, a steady flow of steam passes through the blower pipe and the exhaust nozzle. The draft is created by the same action as that of the exhaust jet, that is, by the friction between the steam and the gases in the smokebox.

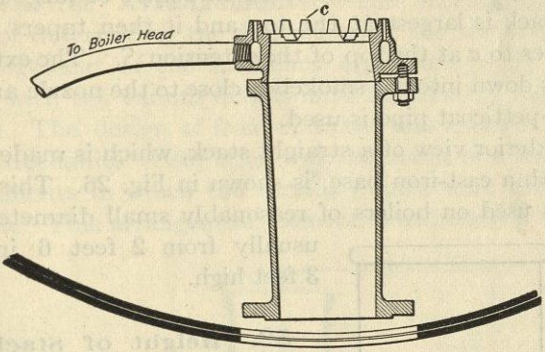


FIG. 24

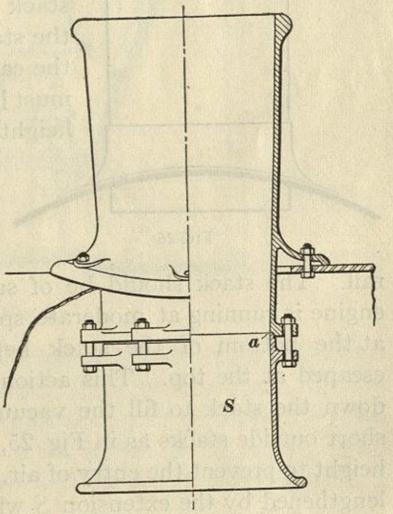


FIG. 25

THE SMOKESTACK

51. Description. The smokestack, or stack, is a cast-iron, sheet-iron, or pressed-steel pipe which is bolted to the top of the smokebox. Its purpose is to carry off the products of combustion from the smokebox to a point above the engine and the train. Fig. 25 is a half outside and a half sectional view of a tapered stack of cast iron, which is used on boilers of large diameter. This stack is largest at the top and it then tapers 1 inch in 12 inches to *a* at the top of the extension *S*. The extension *S* extends down into the smokebox close to the nozzle and therefore no petticoat pipe is used.

An exterior view of a straight stack, which is made of sheet iron with a cast-iron base, is shown in Fig. 26. This style of stack is used on boilers of reasonably small diameter and is usually from 2 feet 6 inches to 3 feet high.

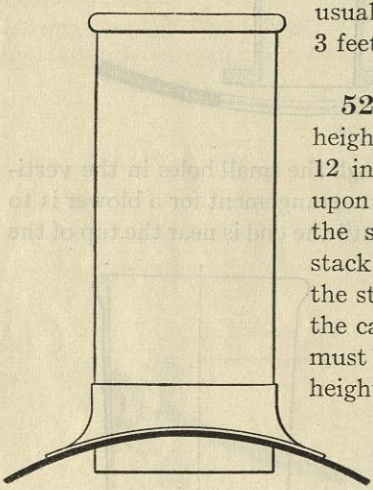


Fig. 26

52. Height of Stack.—The heights of smokestacks vary from 12 inches to 36 inches depending upon the size of the boiler. On the smaller sized boilers, a long stack can be used, and the longer the stack the better the draft. In the case of large boilers, the stack must be made much shorter and the height is usually determined by the clearance of the right of way. The top of the stack is therefore from 15 feet to 15 feet 6 inches above the rail. The stack should be of such a height that when the engine is running at moderate speeds one exhaust is entering at the bottom of the stack before the preceding one has escaped at the top. This action prevents a rush of cold air down the stack to fill the vacuum in the smokebox. With short outside stacks as in Fig. 25, the stack is not of sufficient height to prevent the entry of air, and the stack is accordingly lengthened by the extension *S* which is bolted to the base of the outside stack. How to determine the diameter of the stack will be explained in another Section.

SMOKEBOX DIMENSIONS

53. Earlier Arrangements.—The most satisfactory method of determining the dimensions of the smokebox, and the arrangement of the smokebox appliances is by experimenting with the various details until satisfactory results are obtained. The design of front end that was approved by the Master Mechanics' Association was the result of a long series of experiments in which the various details were thoroughly tried out. This arrangement however was intended only for coal-burning locomotives that used saturated steam, and therefore did not apply to superheated-steam locomotives. Also the arrangement was generally applicable to front ends of reasonably small diameter, or from 50 inches to 70 inches, while modern smokeboxes may have a diameter up to 105 inches.

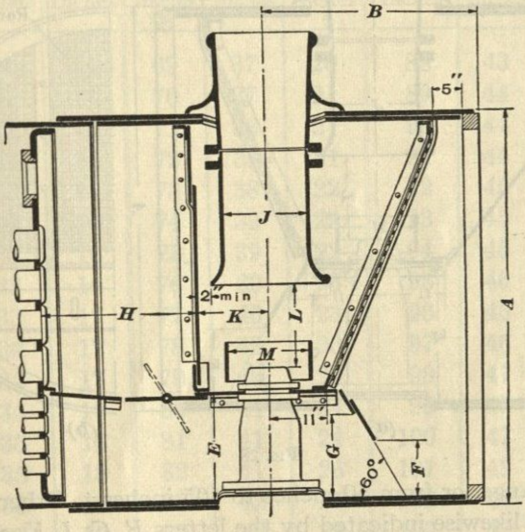
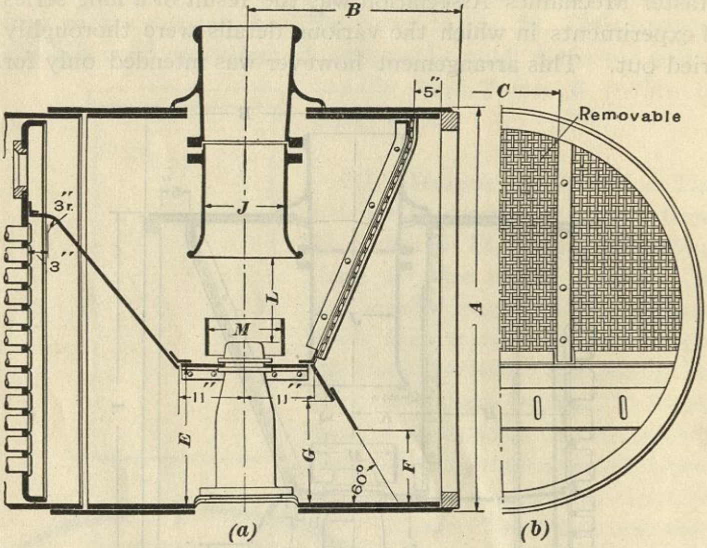


FIG. 27

54. Smokebox Standards.—The American Locomotive Company has adopted standards that cover the arrangement of smokebox details. The standard arrangement for different sizes of smokeboxes can be obtained from Tables II, III, and IV, which give dimensions at the points indicated by the reference letters in Figs. 27 and 28. For example, *A* in Table II refers to dimension *A* in Figs. 27 and 28, or to the diameter of the smokebox; hence, all the numbers in the column under *A* in the table are smokebox diameters. By following this column through, it will be noted that the diameters given cover a wide range, or from 50 inches to 105 inches. Other dimensions are likewise indicated by the letters *B*, *C*, *J*, *K*, etc.



(*a*) (*b*)

FIG. 28

55. Locating Position of Stack.—Table II shows how to determine dimension *B*, Figs. 27 and 28, or the distance in inches that the center of the stack should be placed from the front end of the smokebox for any diameter of smokebox from 50 inches to 105 inches. Dimension *B* is found as follows: Assume that the diameter of the smokebox, or *A*, Figs. 27 and 28, is 75 inches; next find the number 75 under *A* in Table II and note the number in column *B* which is opposite it. This is 39; then dimension *B* is 39 inches, or the center of the stack should be 39 inches from the front of the smokebox when the diameter of the smokebox is 75 inches. Dimension *C*, or the width of the center piece of netting Fig. 28 (*b*) for the same diameter of smokebox, is found from Table II in the same way. The number opposite 75 in the column under *C* is 22 inches, which is therefore the width of the middle section of netting. Dimension *C* as determined by the table brings the two outer strips of netting about the same width as the center one, and also allows a proper width of door. The door is to extend the full height, as shown, for smokeboxes up to 90

TABLE II

STANDARD SMOKEBOX DIMENSIONS

For significance of letters, see Figs. 27 and 28
A = Diameter of Smokebox

A Inches	*B* Inches	*C* Inches	*A* Inches	*B* Inches	*C* Inches	*A* Inches	*B* Inches	*C* Inches
50	31	14	69	37	20	88	43	27
51	31	14	70	37	21	89	44	27
52	31	15	71	38	21	90	44	27
53	32	15	72	38	21	91	44	28
54	32	15	73	38	22	92	45	28
55	32	16	74	39	22	93	45	28
56	33	16	75	39	22	94	45	29
57	33	16	76	39	23	95	46	29
58	33	17	77	40	23	96	46	29
59	34	17	78	40	23	97	46	30
60	34	17	79	40	24	98	47	30
61	34	17	80	41	24	99	47	30
62	35	18	81	41	24	100	47	31
63	35	18	82	41	25	101	48	31
64	35	19	83	42	25	102	48	31
65	36	19	84	42	25	103	48	32
66	36	19	85	42	26	104	49	32
67	36	20	86	43	26	105	49	32
68	37	20	87	43	26			

inches in diameter. For diameters 90 inches and over, a door 30 inches high is used.

56. Position of Netting.—The netting is placed in accordance with the measurements given in Figs. 27 and 28 and reference does not have to be made to the tables to determine its position. As shown, the top of the netting is placed 5 inches from the front of the smokebox and 11 inches from the center of the stack or exhaust pipe. With the netting located as shown, for any smokebox diameter given in Table II the clear area through the netting, or the gas area as it is usually called, will be one and one-quarter times the internal diameter of the tubes and flues. The term *clear area* means the total area of the openings in the netting. The foregoing statement holds true when the netting is designed in the first

TABLE III

DIMENSIONS FOR STANDARD CAST-IRON STACK EXTENSION

For significance of letters, see Figs. 27 and 28

J = Diameter of Stack Extension

J Inches	*K* Inches	*L* Inches	*M* Inches
11	11	13	9
12	12	13	10
13	12	14	11
14	13	14	12
15	13	15	13
16	14	15	14
17	14	16	15
18	15	16	16
19	15	17	17
20	16	17	18
21	16	18	
22	17	18	
23	17	19	
24	18	19	

place with a total clear area of 50 per cent., which means that the area of the openings is one-half the total area of the netting. However, if a netting is applied with a clear area of less than 50 per cent., the dimension given for *B* in Table II will not apply. In such an event the smokebox must be lengthened so as to permit the use of a netting that will give the minimum clear area allowable, or one and one-quarter times the gas area.

57. Dimensions K, L, and M.—Dimensions *K*, *L*, and *M*, Fig. 27, can be obtained from Table III in where the diameter *J* of the cast-iron stack extension is known. Dimension *K* is the distance between the diaphragm and the center of the stack. Dimension *L* is the distance between the top of the nozzle and the base of the stack, and dimension *M* is the diameter of the short draft pipe which is placed around the exhaust nozzle. This pipe when used aids the draft to sweep the table plate clear of cinders. Let it be assumed that the stack has been measured and the diameter *J*, Figs. 27 and 28 (*a*), is found to be 18 inches. By reading Table III in the same way as has been explained for Table II, dimension *K* is found to be 15 inches, and dimension *L*, 16 inches. Dimension *K* is the minimum distance between the center of the stack and the diaphragm in a superheater locomotive, with a clearance of 2 inches between the diaphragm and the stack extension as shown. If necessary, the dimension *K* can be reduced by cutting 2 inches off the back of the extension casting.

58. Height of Table Plates.—Dimension *E*, or the height of the table plates, Figs. 27 and 28, is not determined from Tables II, III, or IV, but depends on the number of flues and tubes that are used. The height of the table plates must be such that the area beneath them is equal to the total internal area of the tubes and flues in the boiler. By the area beneath the plate is meant the area of a piece of plate which, if placed vertically, would fill completely the space between the smokebox and the table plate. The term *gas area* is usually applied to the total cross-sectional area of the tubes and flues. The foregoing applies when outside steam pipes are used, as with superheater engines. With inside steam pipes, the dimension *E*, Fig. 28, is made 15 per cent. more than the total gas area. Under the conditions shown in Fig. 27 the table plates are not to be placed higher than the bottom row of superheater flues.

59. Height of Damper.—The maximum height of the damper is indicated by *G*, Figs. 27 and 28, and the minimum opening by *F*. These dimensions are not determined from the tables, but like dimension *E*, they depend on the total gas area. When the damper is at height *G*, the area under it should be 85 per cent. to 90 per cent. of the total gas area. When the damper is at height *F*, the area under it should be 63 per cent. to 68 per cent. of the total gas area. The damper may be moved between the limits *F* and *G* until the proper draft is produced. The damper should be set at an angle of 60 degrees in all cases.

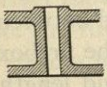
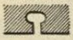
60. Position of Diaphragm.—Dimension *H*, Fig. 27, or the distance between the front tube-sheet and the diaphragm, for a superheater engine, can be found from Table IV. In this table, the heading Number of Rows Deep of the second column refers to the number of flues when counted vertically. The heading Number of Rows Wide above the other columns refers to the rows of tubes when counted horizontally. Assume that, with the improved through-bolt type of header, the superheater flues are five rows deep and that they are from eight to nine rows wide. Opposite the number 5 in the column headed Number of Rows Deep, the number 33 is found in the column headed 8 to 9, hence the correct position of the diaphragm is 33 inches from the front tube-sheet. With the same number of flues deep and wide but with the **T**-bolt type of superheater header, the diaphragm is placed 21 inches from the tube-sheet. The height of the plate, as already explained, depends upon the gas area or the total internal area of the tubes and flues.

The position of the diaphragm with a saturated-steam engine is not given in the tables, but can be found in Fig. 28 (*a*). This figure shows that the bottom end of the diaphragm is placed on the table plate 11 inches from the center of the stack. The upper end is secured to an angle iron directly below the steam pipe. The bend in the plate begins 3 inches from the tube-sheet, and is made with a radius of 3 inches.

61. Length of Smokebox.—When the diameter of the smokebox, the stack diameter, and the flue arrangement are given for a superheater locomotive, the length of the smokebox can be readily found from the tables. With a smokebox diameter of 80 inches, dimension *B*, Fig. 27, according to Table II, is 41 inches. If the stack diameter is 20 inches, dimension *K*, Table III, is 16 inches. If the superheater flues are 6 rows deep and 8 to 9 rows wide, dimension *H*, Table IV, is 37 inches. The total length of the smokebox is therefore 41+16+37=94 inches, or 7 feet 10 inches.

TABLE IV

DISTANCE BETWEEN FRONT TUBE-SHEET AND DIAPHRAGM, DIMENSION H, FIG. 27

Style of Header	Number of Rows Deep	*H*		
		Number of Rows Wide		
		5 to 7	8 to 9	10 to 12
		Inches	Inches	Inches
 *Improved Through-Bolt*	2	19		
	3	24	25	
	4	28	29	30
	5	30	33	37
	6		37	38
 *Tee-Bolt*	3	16	16	16
	4	18	18	18
	5	21	21	21
	6		24	24

THE FIREBOX

62. General Description.—A section taken lengthwise through a locomotive firebox is shown in Fig. 2 *(a)*. The firebox is the furnace or box in which the fuel is burned, and the sheets which comprise it are surrounded by water on all sides. The heat of the fire is transmitted to the water through the sheets, hence there is an exceedingly rapid generation of steam around the firebox.

The firebox is made up of five sheets, the back tube-sheet, the crown sheet, the back, or door, sheet, and the two side sheets. A firebox with a combustion chamber as shown requires an inside throat sheet. The bottom of the firebox is formed by the grates.

The side, the door, and the crown sheet are usually made from $\frac{3}{8}$-inch plate, this thickness having been found to give the best results, and the tube-sheet is either $\frac{1}{2}$ or $\frac{5}{8}$ inch thick.

With the older types of locomotives having the firebox between the frames, the width of the firebox was about 3 feet and the length from 5 to 8 feet. The grate area varied between 15 and 24 square feet. With modern locomotives, the firebox is raised from between the frames and the width and length are increased until the width is now anywhere from 3 feet 6 inches to 10 feet and the length from 5 to 15 feet. The grate area varies from 20 to 110 square feet, depending upon the requirements of the locomotive.

63. The space between the inner and the outer sheets of a firebox is called the water leg. The water leg varies in width from 3 to 7 inches at the bottom and gradually increases in width toward the top. The greater width at the top allows for the free circulation of the steam bubbles as they rise to the surface of the water. The bottom of the water leg is formed by a cast-steel or wrought-iron ring *o* called the foundation ring, or mud ring, to which the outside sheets and the firebox sheets are riveted. The rivets pass through both sheets and the ring and are headed on both sides. From two to six arch tubes *b* are placed lengthwise in the firebox, the number used depending on the width of the box. These tubes serve the double purpose of aiding the circulation of the water through the boiler and of supporting the firebrick arch b_1.

CONSTRUCTION OF FIREBOX

64. Firebox Sheets.—The several sheets of a firebox are joined together by means of a riveted joint, a single row of rivets of about ¾ inch in diameter being used. Fig. 29 shows a single-riveted lap joint such as is used in firebox construction. It is advisable, as far as possible when this style of joint is used, to keep the heads of the rivets away from the direct action of the fire. Otherwise the amount of the metal at one place is liable to cause overheating and the seam soon starts to leak. To overcome the disadvantage of having the rivet heads on the fire side, a style of rivet shown in Fig. 30 is used. This style is used on the flanges of the tube and the door sheets from the bottom of the sheet up to a height above that of the fire. It is evident that with such a method of riveting the action of the flames on the rivet heads is much less than with the type shown in Fig. 29, because the heads have very little more metal than the thickness of the plates.

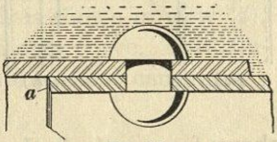


FIG. 29

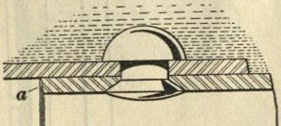
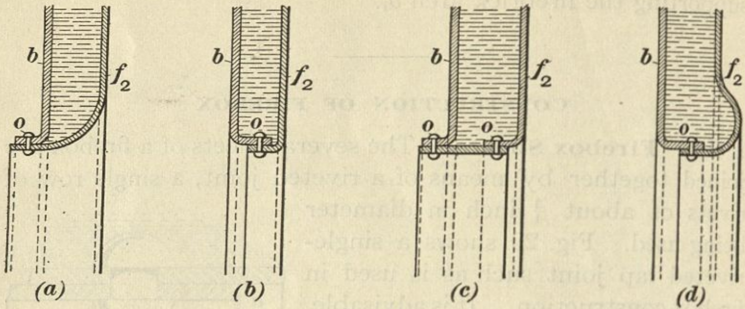


FIG. 30

65. On the fire side of the seam, Figs. 29 and 30, is shown a recess *a* which is made by calking the joints steam-tight. Where possible, especially in firebox work, it is an advantage to calk both the water and the fire sides, as this makes a much more efficient joint so far as leaking is concerned.

Instead of having the side sheets and crown sheet separate, plates are now made of sufficient size to make the entire side sheets and crown sheet in one piece. This is a great advantage, as it does away with the riveted joints between the two sheets and gives a more effective heating surface.

66. Door Hole.—The door hole in the back, or door, sheet is constructed in a number of different ways. Fig. 31 shows four methods that are used to connect the back sheet f_2 to the back head *b*. The sheet f_2 surrounding the door opening is flanged, view (*a*), to a large radius and extends through to the outer sheet *b*, the two sheets being riveted together at *o*. In view (*b*), the door sheet f_2 is shown flanged



(*a*) (*b*) (*c*) (*d*)

FIG. 31

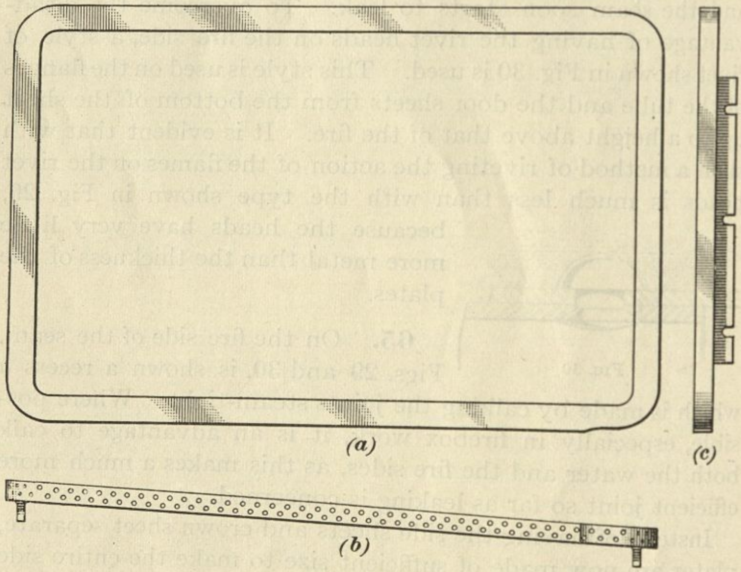

(*a*) (*c*) (*b*)

FIG. 32

outwards and the back head *b* is flanged inwards, and the two are riveted together at *o*. View (*c*) shows what is called the sleeve door, in which both sheets are flanged outwards, and a separate piece is rolled to the shape of the door hole and is welded and then riveted to the sheets at *o*. Owing to the continual expansion and contraction caused by the alternate heating and cooling of the inner sheet around the fire-door as the door is opened and closed, the sheet when flanged in a single curve as in views (*a*), (*b*), and (*c*) is liable to crack. A method of overcoming this is shown in view (*d*), where the door sheet f_2 is flanged to an ogee curve. This construction allows considerable movement without causing any rupture or distortion of the sheet.

67. The Foundation Ring.—The foundation ring, also called the firebox ring and the mud ring, is a casting or forging that separates the inside and outside firebox sheets at the bottom, and to which those sheets are riveted.

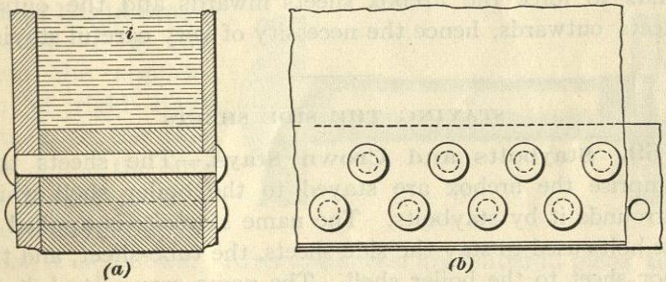


Fig. 33

Fig. 32 (*a*) shows the foundation ring as viewed from the top, and views (*b*) and (*c*) as seen from the side, and rear. Fig. 33 (*a*) is a section taken through the ring and the firebox sheets, and view (*b*) is an exterior view which shows how the outer sheet is riveted to the ring.

The ring, Fig. 32 (*a*), is rounded so as to eliminate the sharp corners. The two sheets, Fig. 33 (*a*), are secured to the ring by two rows of rivets which are headed on each side. View (*b*) shows the zigzag method of riveting which is always used when double riveting is resorted to. In some cases, instead of full heads on the rivets on the fire side as shown in view (*a*), the sheet is countersunk and the rivets are driven in much the same manner as shown in Fig. 30.

Foundation rings are made from 3 inches to 7 inches wide and from $2\frac{1}{4}$ inches to $4\frac{1}{2}$ inches thick, depending on the width of the water legs and whether one or two rows of rivets are used.

68. **Water Leg.**—The water leg *i*, Fig. 33 (*a*), is the space between the outer and inner sheets of the firebox. It is a very important part of the water space of the boiler because, containing water, it prevents the firebox sheets from becoming overheated by the extreme heat of the fire. The water evaporates very rapidly in the water leg and this causes a continuous circulation of water around the firebox. On account of the head of water in the boiler, the pressure at the bottom of the water legs is slightly greater than that at the top. The pressure due to the head of water and the steam pressure tends to force the firebox sheets inwards and the outside sheets outwards, hence the necessity of very careful staying.

STAYING THE SIDE SHEETS

69. **Staybolts and Crown Stays.**—The sheets that comprise the firebox are stayed to the boiler shell which surrounds it by staybolts. The name *staybolts* is applied to the bolts used to stay the side sheets, the tube-sheet, and the door sheet to the boiler shell. The name *crown staybolts* or *crown stays* is applied to the bolts used to stay the crown sheet to the roof sheet.

70. **Staybolts.**—Staybolts are of two general classes, rigid and flexible. Rigid staybolts are applied so that each end is rigidily connected to the sheets, hence the name. A flexible staybolt is one in which one end is rigidly connected to one sheet while the opposite end is free to move in the other sheet, or both ends may be rigidly connected and the middle portion may be constructed so as to be flexible. Staybolts are necessary so that the firebox sheets will withstand the strains

due to the steam pressure, and to the expansion and contraction of the sheets. Staybolts constitute one of the most important details in boiler construction, the material, the design, and the method of application being all of equal importance. A true stay is one in which the bolt is at right angles to the sheets which it connects. Therefore it is necessary that all staybolts be at right angles to the sheets or as near so as possible.

Staybolts are manufactured from refined wrought iron to standard specifications, and are from $\frac{7}{8}$ to $1\frac{1}{8}$ inches in diameter. If of the rigid type, they may be threaded throughout their whole length or they may have their center portion turned down to a slightly smaller diameter.

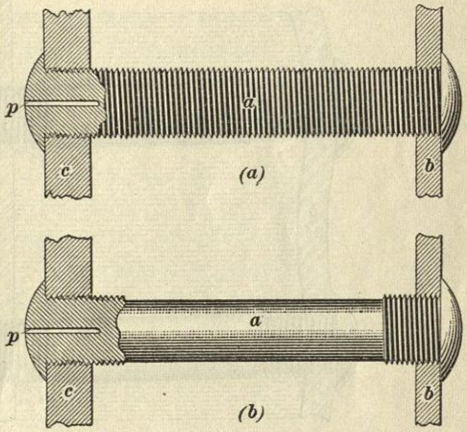


FIG. 34

71. Application of Rigid Staybolts.—Fig. 34 shows the application of rigid staybolts *a* to the side sheet *b* and the outside firebox sheet *c*. The method of application is as follows: After the sheets are bolted in place, the holes are tapped out with a long tap so that the threads of one sheet are in alinement with the threads of the other. The staybolts are then screwed into place and adjusted so that there is about $\frac{1}{4}$ inch of stock on the outside of both sheets to provide metal for heading over. Any surplus is cut off and the ends are riveted over as shown. The standard thread used on staybolts is twelve threads to the inch. Staybolts frequently break, and to enable warning to be given when this happens, a tell-tale hole *p*, $\frac{3}{16}$ inch in diameter, is drilled $1\frac{1}{4}$ inches deep in the outer end of the bolt. As the bolts invariably break at the outer ends steam escaping from the hole will give warning. The tell-tale hole must always be kept open.

Hollow staybolts are sometimes applied, this type having holes entirely through them. The holes serve the purpose of supplying air direct to the firebox above the fire, two rows being placed above the fire line.

72. Movement of Firebox Sheets.—There is a more or less continuous movement of the firebox sheets and therefore of the staybolts, due to the alternate high and low temperatures of the firebox, which cause the sheets to expand and contract. The variations in temperature are the greatest when firing up a cold engine. The movement of the sheets is more pronounced at the top and the ends of the firebox, because the sheets are rigidly connected at the bottom to the foundation, or mud, ring and any movement must be upwards and lengthwise. As the temperature of the inner sheet is greatly in excess of that of the outside sheet, the expansion and contraction of the inner sheet is the greater. This greater movement of the inner sheet causes stresses to be set up in the staybolts, which will eventually break them, the fracture in most cases occurring at the outer sheet. The effect of the movement of the firebox sheet is shown in Fig. 35. This figure shows a section through a part of the firebox sheet, *a*

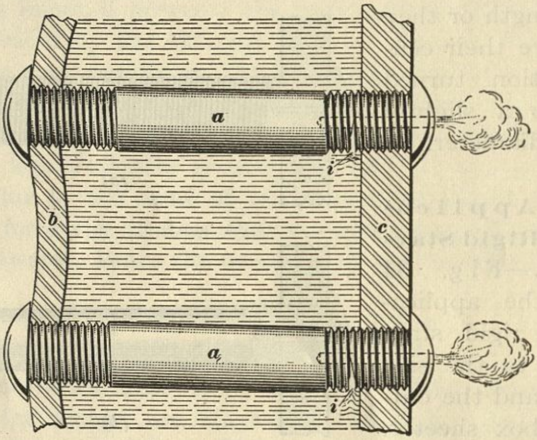


FIG. 35

being the staybolts, *b* the firebox sheet, and *c* the outside firebox sheet. The application of heat to the firebox sheet *b* causes it to expand much more rapidly than the outer sheet *c*, which is comparatively cool. This movement distorts the inner sheet *b*, as shown, and causes the sheet and the staybolts to assume new positions in relation to the outer sheet. On becoming cool, the sheet tends to resume its original position. This continual movement soon causes a fracture in the staybolt, as shown at *i*, and the bolt will not carry the load for which it was designed.

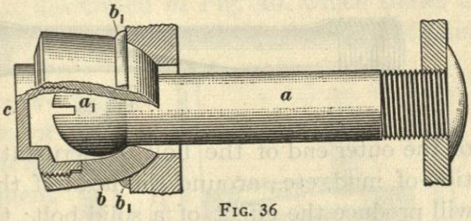


FIG. 36

73. Application of Flexible Staybolts.—A flexible staybolt is one that is designed to allow for the difference in the expansion and contraction of the inner and the outer firebox sheets without placing undue strains on the sheets or the bolt. This type of staybolt is now in general use. The flexible staybolt shown in Fig. 36 consists of a bolt *a* having a spherical-shaped head a_1 which fits snugly in a sleeve *b*. The sleeve is welded to the outside firebox sheet, the metal forming the weld being shown at b_1. A cap *c* which makes a tight joint is screwed into the outer end of the sleeve. The method of application is as follows: A hole is drilled in the outer sheet and the sleeve is welded in place. The staybolt tap is then run through the sleeve and the hole in the firebox sheet is tapped out. The bolt is screwed into place, the surplus cut off, the bolt headed over on the fire side, and the cap nut applied. The earlier types of flexible staybolts had the sleeve screwed into the sheet instead of welded to it. This type of staybolt is illustrated in Fig. 37.

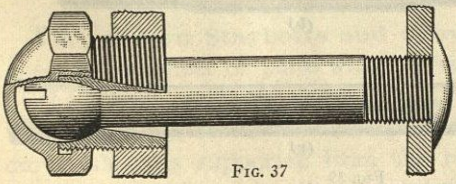


FIG. 37

Staybolts of either of these kinds allow the firebox sheet to move more or less without causing undue stress on the sheet or the outer end of the bolt. Incrustation or the accumulation of mud, etc., around the head of the bolt, in the sleeve, will produce the effect of a solid bolt; therefore a mixture of graphite and oil is applied around the bolt head when the cap is removed.

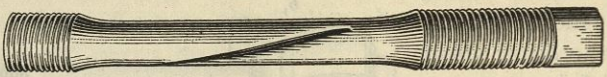


FIG. 38

74. The flexible staybolt shown in Fig. 38 differs from that shown in Figs. 36 and 37. The reason for the flexibility possessed by this type of staybolt can be more readily understood if the process of manufacture is considered. This is illustrated in Fig. 39. The bolt is first slotted as shown in view (*a*), the sharp edges are rounded and the surface of the slot smoothed as in (*b*), then the body section is reduced by rolling to the form shown in (*c*). The bolt is then twisted one-third of a turn, threaded and squared, and the tell-tale hole is drilled in it. The middle portion of the bolt may be compared to a rope with two strands loosely twisted. When the bolt is subjected to a twisting strain the middle portion

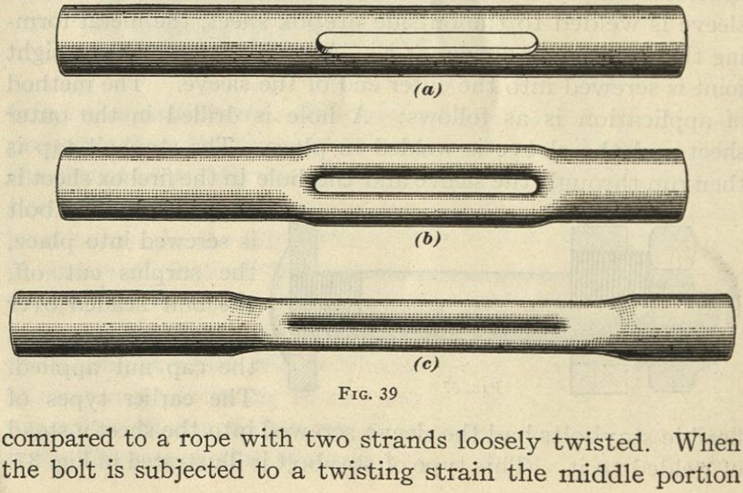


FIG. 39

of the bolt will give and allow the sheet to move without distortion and without subjecting the staybolts to severe strains. This action is illustrated in Fig. 40, which shows a portion of the firebox sheets connected by staybolts of this type. As the sheet *b* moves, the central portions of the bolts open or close, depending on the direction of the movement of the sheets, and the flexibility of the bolts prevents the strains on their ends such as occur when the staybolts are rigid.

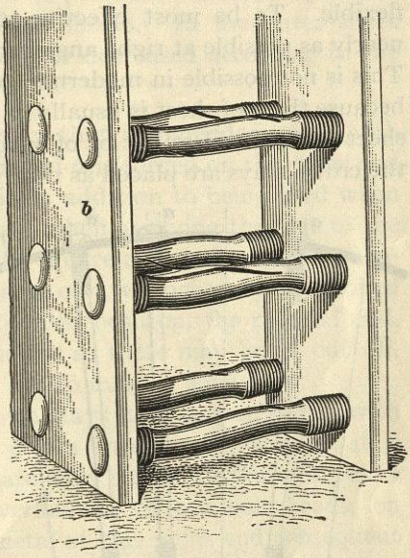


FIG. 40

75. In some cases, the entire installation is of flexible staybolts, while in other cases they are installed only in what is known as the breaking zone which is that part of the firebox where the tendency for breakage is greatest. The breaking zone usually comprises two or three upper rows along the sides, the first six or eight rows toward the ends, and the outer rows on the back head and throat sheet.

STAYING THE CROWN SHEET

76. Crown Staybolts and Crown Bars.—The crown sheet is the sheet or plate which forms the top, or the roof, of the firebox. The crown sheet may be made separate from the side sheets, or the sheets may be made in one piece. The crown sheet is supported from the roof sheet by crown or radial staybolts, or by the crown-bar method. In modern practice, staying by crown bars has been almost entirely superseded by the staybolt method.

77. Crown Staybolt.—A crown staybolt, or crown stay, is a staybolt that is used to connect the crown sheet with the roof sheet. It serves the same purpose for the crown sheet as the staybolts do for the side sheets. As with the firebox staybolts, the crown staybolts may be either rigid or flexible. To be most effective, the staybolts should be as nearly as possible at right angles to the surfaces they support. This is not possible in modern locomotive-boiler construction, because the roof sheet is usually of large radius, and the crown sheet is more or less flat or of small radius. Therefore, when the crown stays are placed as nearly as possible at right angles to the crown sheet their arrangement will resemble the spokes of a wheel or will be radial, and they are generally referred to as *radial stays*.

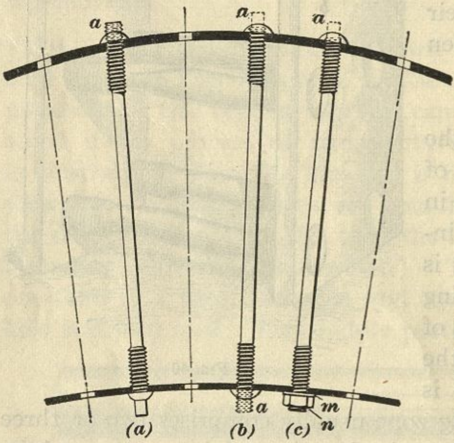


FIG. 41

78. Rigid Crown Stays.—Fig. 41 shows three different types of rigid crown staybolts all of which are applied in a different manner. View (*a*) shows a *button-head crown bolt*, so called because of the shape of the lower end. This type of bolt is applied from the firebox side, the staybolt being screwed up snugly against the under side of the crown sheet and through the roof sheet, and the outer end riveted over. The square projection on the firebox end of the bolt permits of its being screwed into place. View (*b*) shows a stay that is screwed through both sheets and both ends riveted over. View (*c*) shows a stay that is applied through the roof sheet. The stay is then riveted over on the outer end and a copper washer *m* and a nut *n* are applied to the firebox end of the bolt. The parts *a* on the ends of the bolts, views (*a*), (*b*) and (*c*), show the ends before they are riveted over. Screw crown stays usually have the middle portion of the bolt turned down slightly smaller in diameter than the threaded portion, as this aids in the application of the bolt. All staybolts and crown stays should be placed 4 inches to 4½ inches apart each way in the firebox sheets. In the outer sheet this distance may be increased or decreased according to the curvature of the sheet.

79. With the style of stay that is riveted over at both ends as in view (*b*), a square end *a* is forged on the outer end of the bolt. This square end in addition to being used when threading the bolt is also used when applying the bolt to the boiler. To apply the bolt, the square end is placed in a pneumatic tool and run into place, or a wrench may be applied to this end. When the stay is in position, the squared end, together with such other surplus as there may be, is cut off, only enough material being left to make a good head.

In all cases where the crown stays have button heads with squared ends next to the crown sheet as in view (*a*), it is advisable to cut off the square ends before the boiler is put in service. This prevents overheating of the bolt heads, on account of the amount of metal at this point and consequent leakage. The most satisfactory way of cutting off the ends is to fill the boiler with water until the crown sheet is covered and then cut off the square ends below the button heads with an oxyacetylene torch. The boiler is filled with water so as to prevent the heat of the torch from starting the joint between the bolt and the sheet. In the process of machining a button-head crown bolt, view (*a*), the part of the head that comes against the sheet is slightly undercut or dished out. When the head is tightened against the sheet, the outer edge of the head comes in contact with the sheet first, and as the bolt is tightened the head makes a steam-tight joint with the sheet.

80. Flexible Crown Stays.—Flexible crown stays prevent the expansion and contraction of the crown sheet from setting up undue strains in the sheet or the staybolt.

Fig. 42 shows two types of crown stays which are applied in a different manner.

The type of stay shown in view (*a*) is screwed up tight through the crown sheet, the nut *a* is applied to the opposite end and brought to its bearing in the sleeve a_1, which has been previously welded to the roof sheet. The cap nut a_2 is then screwed into the sleeve.

A stay of the type shown in view (*b*) is applied as follows: The roof sheet and crown sheet are punched or drilled as usual and the hole in the roof sheet is reamed and tapped for the sleeve *a*, which is electrically welded to the sheet, the welding metal being shown at a_1. After the sleeve is welded, the tap is run through the sleeve into the crown sheet and the hole is tapped out. The bolt is inserted through the sleeve and the lower end is screwed through the crown sheet. A riveting plug is then applied to the outer end of the bolt, the inner end is riveted over, and the cap a_2 is applied.

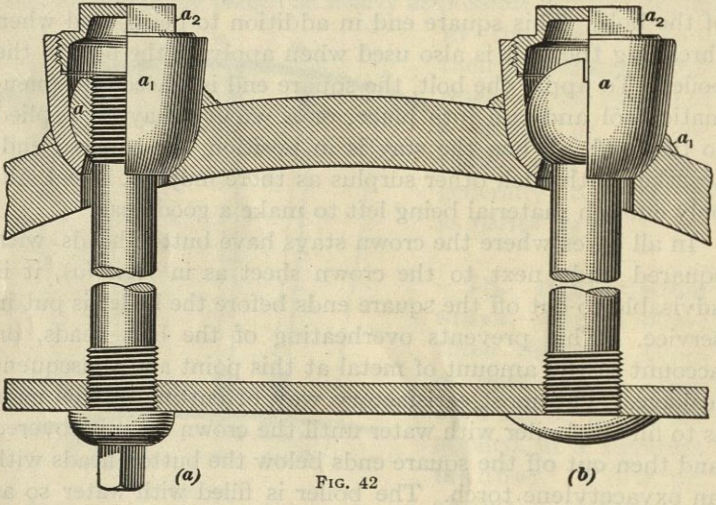


FIG. 42

81. Fig. 43 shows how a portion of the roof sheet appears when flexible crown stays of the types described are used. In the illustration, the cap nuts have not yet been put in place.

As with the flexible staybolts, the earlier types of flexible crown stays had the sleeves screwed into the sheet instead of welded to it. The sleeves when welded are less liable to leak than when threaded. The staying of the crown sheet by crown stays in addition to being more efficient than the crown-bar method has the advantage of making the crown sheet practically self cleaning. On account of the curve of the sheet, any impurities that settle on it are washed off by the circulation of the water.

82. Crown-Bar Method.—With the steam dome placed over the crown sheet, as was the general practice with the older types of boilers, it was necessary to use the crown-bar method of supporting the crown sheet. The reason was that the opening made in the roof sheet by the dome prevented the section of the crown sheet beneath it from being supported by crown staybolts. However in some cases that part of the crown sheet not under the dome was supported by crown staybolts instead of crown bars.

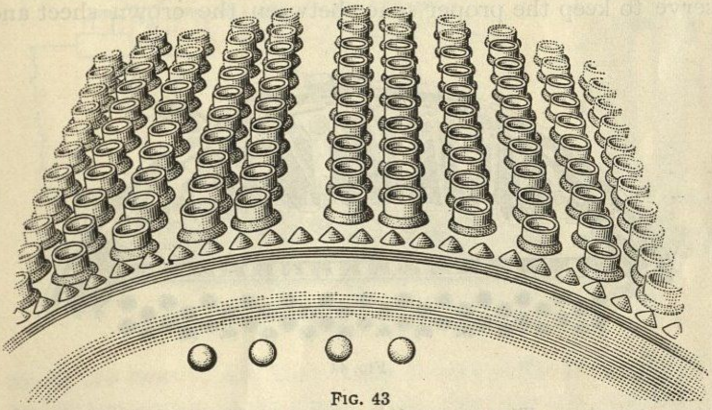


FIG. 43

In Fig. 44 the cylindrical part of the boiler in front of the tube-sheet is removed so that the crown bar over that part of the crown sheet next to the tube-sheet may be seen. Fig. 45 is an enlarged view of a portion of the arrangement shown in Fig. 44.

83. The crown bar *a*, Fig. 44, as shown in Fig. 45 (*b*), is generally made of two pieces of plate spaced about $1\frac{1}{4}$ inches apart, except at the ends, which are welded together. The ends of the bars may be connected by pins a_1 to the brackets a_2 on the roof sheet, as shown in Fig. 44, or the ends may have feet that rest upon the crown sheet, where it is riveted to the side sheets. The crown bolts a_3, Fig. 45 (*a*) and (*b*), are screwed through holes punched and tapped in the crown sheet, and pass up through the thimbles a_4 and between the two sections of the crown bar. Washers a_5, the ends of which fit over the sides of the crown bar, are placed on the bolts, and the nuts a_6 are then applied and drawn up tight. The thimbles a_4 serve to keep the proper space between the crown sheet and the crown bar. The crown bars are connected to the brackets, or **T** irons a_7, on the roof sheet by the crown-bar links a_8 and slings a_9. The lower ends of the links are connected to the crown bars by the pins a_{10}, and the upper ends of the slings are fastened to the bracket by the pins a_{11}. The links and the slings are pinned together as shown. The braces *b*, Fig. 44, are used to brace the back head to the roof sheet. In some installations the lower ends of the slings are pinned directly to the crown bars. The threads on the crown bolts, Fig. 45, are cut so as to make a steam-tight joint, and the bearing of the button on the head of the bolt against the plate is also designed to prevent a leak even if the threads fail to do so.

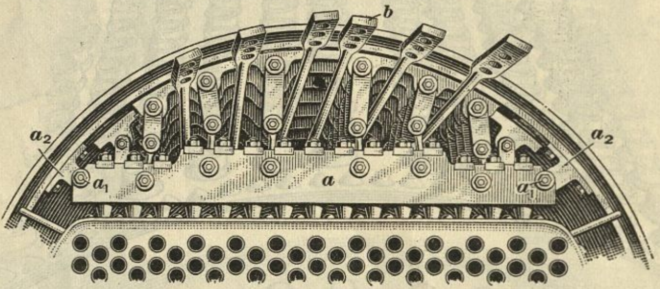


FIG. 44

84. The objections to the crown-bar method of staying are as follows: The crown bars take up considerable water space, are heavy, and they make it very difficult to keep the top of the crown sheet clean. Also they are not adapted to other than flat sheets.

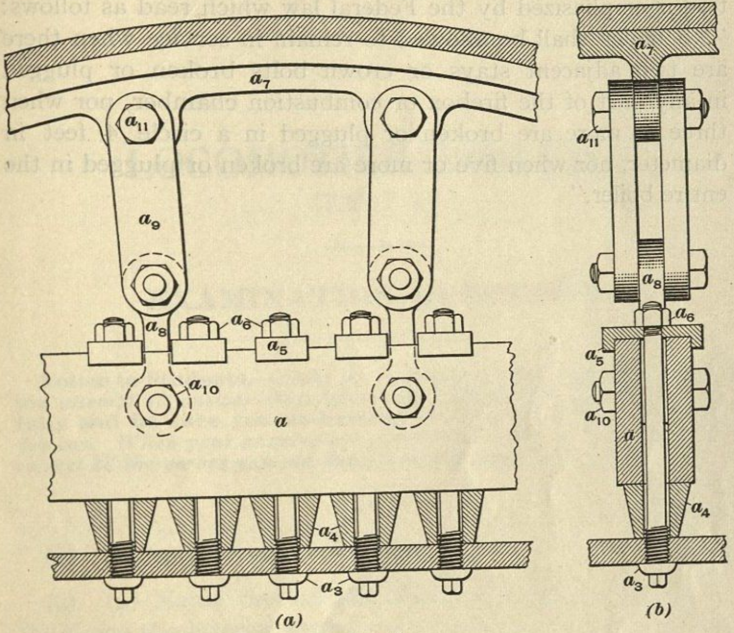


FIG. 45

85. Staying Sheets on Oil-Burning Locomotives.—On oil-burning locomotives, the staying of the crown sheet requires particular attention on account of the liability of the heads of the staybolts to be burned off by the intense heat of the fire. To overcome this, and also to have an added security, the bolts are enlarged at the fire end, as shown in Fig. 46, and threaded on a taper so that in case of an overheated sheet, the sheet will not pull away from the bolt so readily as in the case of a straight threaded bolt.

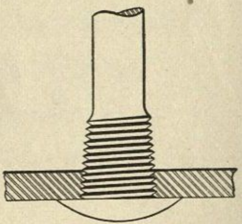


FIG. 46

86. Importance of Staybolts.—That staybolts and crown bolts are a very important detail in boiler construction is emphasized by the Federal law which read as follows: "No boiler shall be allowed to remain in service when there are two adjacent stays or crown bolts broken or plugged in any part of the firebox or combustion chamber, nor when three or more are broken or plugged in a circle 4 feet in diameter, nor when five or more are broken or plugged in the entire boiler."

LOCOMOTIVE BOILERS

(PART 1)

EXAMINATION QUESTIONS

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(1) Define a locomotive boiler.

(2) (*a*) Name the exterior sheets of a locomotive boiler. (*b*) Name the interior sheets.

(3) Name the different classes of boilers according to their shape.

(4) What is: (*a*) a narrow firebox? (*b*) a wide firebox?

(5) Why do modern boilers have wide fireboxes?

(6) Describe an extended wagon-top boiler.

(7) What are the joints at the junction of the boiler courses called?

(8) What is the name applied to the joint that connects the ends of a course?

(9) What is the purpose of the smokebox?

(10) How is the draft affected by: (*a*) lowering the diaphragm apron or damper? (*b*) by raising the damper?

(11) Name the draft plates in a locomotive smokebox.

(12) What is the purpose of the netting?

(13) What is the general rule in regard to the size of the exhaust nozzle?

(14) What is the effect if the nozzle is too small?

(15) Explain how the exhaust steam produces a draft.

(16) Why is a blower provided, and what does it consist of?

(17) What is used to connect the firebox sheets to the boiler shell?

(18) Name the two general classes of staybolts.

(19) Why are tell-tale holes drilled in the outer ends of rigid staybolts?

(20) How is the crown sheet supported in modern boilers?

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